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Japan and the Sea

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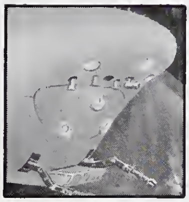
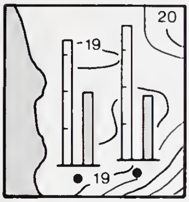
contents





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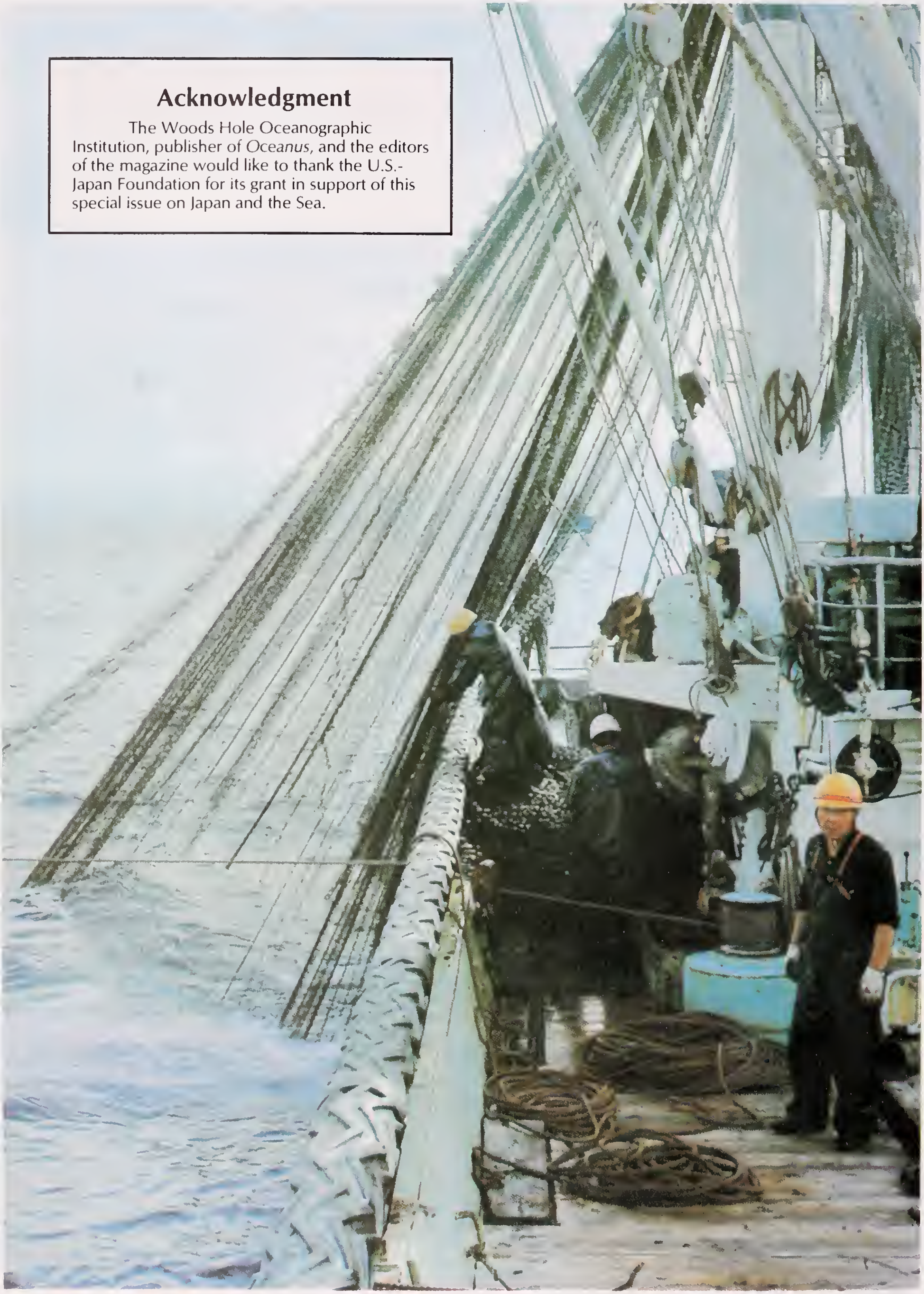


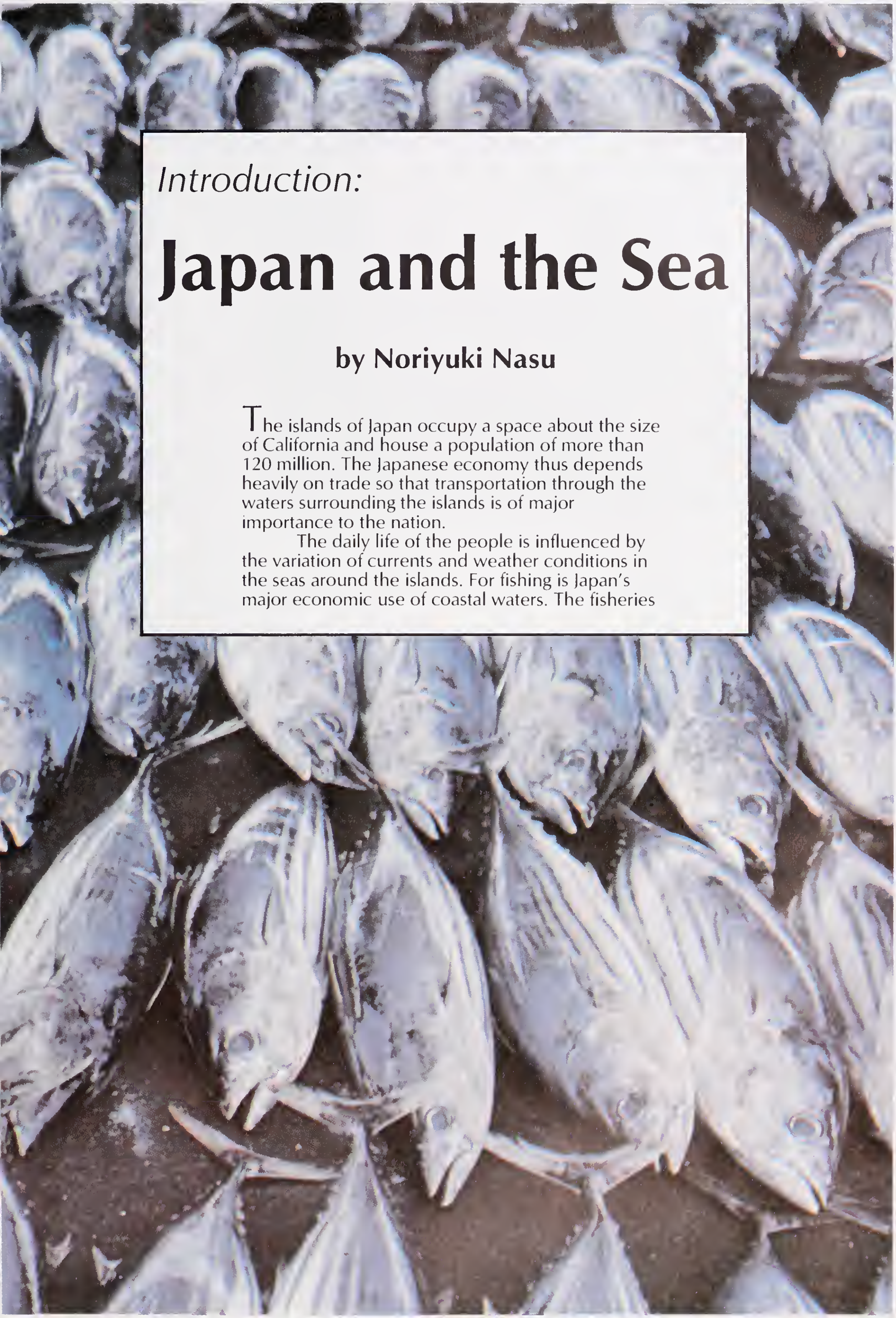
Introduction:

Japan and the Sea

by Noriyuki Nasu

The islands of Japan occupy a space about the size of California and house a population of more than 120 million. The Japanese economy thus depends heavily on trade so that transportation through the waters surrounding the islands is of major importance to the nation.

The daily life of the people is influenced by the variation of currents and weather conditions in the seas around the islands. For fishing is Japan's major economic use of coastal waters. The fisheries



A fisherman and his wife spread out their nets to dry after a day's work in Hiroshima. (Photo Researchers, Inc.)

catch in 1984, the last year for which full figures are available, was about 7.3 million tons. Of these, 1 million tons came from aquaculture. The catch values were 3 trillon yen of fish in 1984. This general trend continues today. For those of you who would like to convert to dollars, the exchange rate these days varies from 150 to 160 yen per dollar.

Naturally, fisheries research is one of the keystones of Japanese marine science. Aside from fisheries, the extraction of natural resources from the seas in the neighborhood of Japan is quite poor, except for salt. There is little oil and gas available from the continental shelf. Japan imports 99.8 percent of its oil.

The Japanese islands have long shorelines. Harbor construction, reclamation projects, and coastal protection from erosion are important industrial activities. At present, more than 50 percent of the coastline has been modified artificially. Many studies are being carried out in the field of ocean space utilization. By the same token, the preservation of coastal areas is a matter of deep concern and has prompted strong environmental and construction regulations.

The Japanese islands are located on the boundaries between the Eurasian and North American continental plates on the one hand, and the Pacific and Philippine oceanic plates on the other. Where one plate subducts under another it is called a subduction zone, which in turn is associated with volcanic activity and earthquakes. Our marine geologists and geophysicists are thus working hard to advance our knowledge of plate tectonics.

Ships are among the best tools we have to investigate the properties of the sea (Table 1). Our vessels are divided into research, survey, observation, and training types. Almost all of our vessels are well equipped by modern standards. For example, the Geological Survey of Japan uses the *Hakurei-maru*, owned by the Metal Mining Agency, to do submarine geology and geophysics work around Japan. Also, the vessel undertakes various international research cruises in the central Pacific. The Japanese National Oil Corporation (JNOC) also uses the *Hakurei-maru* for survey work in the Antarctic.

The Deep Ocean Resources Development Co., Ltd., (DORD) operates the *Hakurei-maru No. 2* in the east and central Pacific to investigate the distribution of deep sea manganese nodules and

Table 1. Representative vessels for marine science and technology in Japan. (Tonnage is generally in gross tonnage)

Hakuho-maru (3,200t., 1967)
Ocean Research Institute, University of Tokyo.
It is the major ocean-going research vessel used for basic research.
It will be replaced by a new 4,000 ton vessel in 1989.
Umitaka-maru (1830t., 1973)
Tokyo University of Fisheries.
Hokkaido University, Nagasaki University, Kagoshima University and some other national universities have similar vessels for fishery research.
Bosei-maru II (1218t., 1958, remodeled in 1978)
Tokai University (private).
Takuyo (2600t., 1983)
Hydrographic Department.
Ryofu-maru (1600t., 1966)
Meteorological Agency.
Hakuryu-maru (1290t., 1988, under construction)
Fishery Agency.
Shinkai 2000 (1981) submersible for 2,000 meters depth.
Natsushima (1553t., 1981) mother ship for Shinkai 2000.
Kaiyo (2840t., 1985) mainly for technical experiments.
Shinkai 6500 (under construction) submersible for 6,500 meters depth.
Japan Marine Science and Technology Center (*JAMSTEC*)
Hakurei-maru (1820t., 1974)
Hakurei-maru No. 2 (2100t., 1980)
Metal Mining Agency

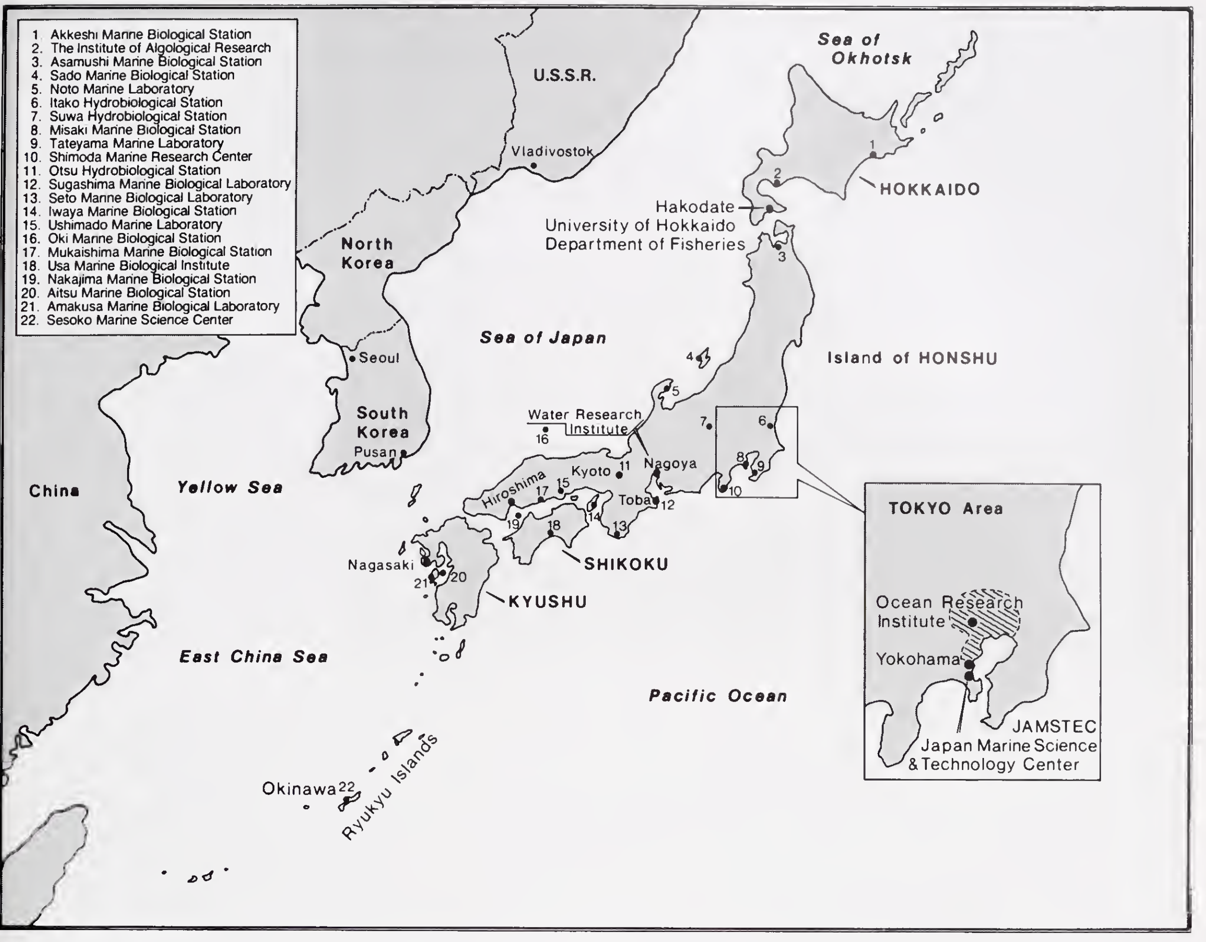


Figure 1. Japan and surrounding regions. Several principal research institutions are shown. Numbers correspond to biological stations or science centers listed in upper left. Additional information on these research stations will be found on page 57.

hydrothermal polymetalic deposits as well as cobalt-rich manganese crust.

We also include submersibles among our tools, even though their number is still few. Aircraft and satellites are also being utilized. The Japanese ocean satellite MOS-1 is expected to be operational this year.

Funding Budgets

One can get some idea of the importance Japan places on the marine sciences by looking at the budgets for some of the areas just mentioned. The total government budget in FY1986 was 191.2 trillion yen. The fiscal year starts on April 1 and ends on March 31. The fisheries share of the fiscal pie was 301.1 billion yen. Harbor construction, reclamation, and coastal protection received 820.7 billion yen. The budget for marine science and technology was 64.4 billion yen.

The budgets for ship surveys among various governmental agencies as well as the academic budgets for national universities in the fields of marine science and technology are so complicated that it is difficult to summarize. But, these funds easily are several times those allocated for marine science and technology.

Some History

The Tokugawa Shogun controlled all of Japan in 1603, closing the country to trade in 1639. It was not reopened again until 1854. During these years, the only contact with the outside world was a small trade route through Nagasaki to China and Holland. This involved only small fishing boats and a few tiny cargo ships.

Commander Matthew C. Perry came to Uraga with the U.S. fleet in 1853 with the intention of forcing Japan to open its doors to trade with the West. Japan accepted his proposal the following year.

The feudalistic era of the Shogun ended in 1868, and was replaced by the Emperor's rule. Thus the era of modern Japan started in this year. Since the start of the modern era, the Japanese people have been eager to absorb western civilization. This same trend can be seen in the marine sciences.

Perhaps, the establishment of the forerunner of the Hydrographic Department in 1871, might be considered the beginning of marine research. Studies of the oceans continued until World War II, when marine research declined. Even after the war,

The visit of the R/V Spencer F. Baird *in 1953 had a great impact on Japanese oceanographers. (Photo courtesy of the Scripps Institution of Oceanography)*

The R/V Hakuho-maru *of the Ocean Research Institute (ORI), University of Tokyo. This is the major Japanese vessel engaged in basic scientific studies of the oceans.*

many scientists were inactive because funding was scarce.

It was not until the visit in 1953 of the research vessel *Spencer F. Baird* of the Scripps Institution of Oceanography, which had a great impact on Japanese oceanographers, that there was a rekindling of large-scale interest in ocean studies.

The research vessel *Ryofu-maru* of the Meteorological Agency initiated the first Japanese study of the deep sea in 1959. The Rockefeller Foundation provided funds for a new 14,000-meter winch wire and a new echo sounder capable of reaching the bottom of the Japan Trench.

In 1962, the Ocean Research Institute (ORI) was established at the University of Tokyo. This institute was founded for basic scientific research. Since then, activities in the fields of marine science and technology have gradually increased. This trend should continue into the immediate future.

International Cooperation

Japanese oceanographers are heavily involved in various types of international cooperation. I see this trend increasing in the future.

The first participation of Japan in an international ocean project was probably the International Indian Ocean Experiments (IIOE), which started in 1960 and terminated in 1962. Since then, Japan has participated in a large number of international cooperative projects. Three examples of these are the International Phase of Ocean Drilling (IPOD), which started in 1975 and became the

Tub boats of Sado Island, used for fishing abalone, top shell, and wakame seaweed. In the winter, the men use the tubs for hook fishing. (Photo courtesy of Japan Marine Products Photo Materials Association)

Ocean Drilling Program (ODP) in 1983; the Kaiko Project in 1984 and 1985, a bilateral study with France of Japanese subduction zones; and a series of geological and geophysical investigations of the New Britain Trench (1984), the Tonga Trench (1985), and the Sundra Trench (1986).

In 1987 and 1988, a cooperative study is planned for the north Fiji basin, where a small-scale rift system exists. This project is planned in conjunction with France.

The author can remember when he joined the *Glomar Challenger* in 1977 for Leg 57 of the IPOD cruise to the area of the Japan Trench. The discovery of the "Ancient Oyashio Landmass," now hiding beneath the deep sea terrace on the landward side of the trench, was really exciting. This discovery had a strong impact on the interpretation of the geological history of the Japanese islands. The excitement of similar discoveries awaits our young oceanographers of today. For Japan is at a crossroad where the obvious path to be taken is an increased utilization of the oceans' resources to meet our national needs. The following articles in *Oceanus* attest to the broad and ever-increasing interest of our scientists in the marine world.

Noriyuki Nasu is Professor Emeritus and former Director of the Ocean Research Institute at the University of Tokyo. He is presently a Professor at the University of the Air, Chiba, Japan.

The Structure of Marine Development in Japan

- Prime Minister
  - Prime Minister's Office *
    - Defense Agency *
    - Economic Planning Agency
    - Hokkaido Development Agency
    - Science and Technology Agency *
      - Japan Marine Science and Technology Center
    - Okinawa Development Agency
    - Environment Agency *
      - National Institute for Environmental Pollution Research
    - National Land Agency *
  - Ministry of Foreign Affairs *
  - Ministry of Education *
  - Ministry of Health and Welfare *
  - Ministry of Agriculture, Forestry, and Fisheries *
    - Fisheries Agency
      - Hokkaido Regional Fisheries Research Laboratory, Tohoku Regional Fisheries Research Laboratory; Tokai Regional Fisheries Research Laboratory, Southwestern Sea Regional Fisheries Research Laboratory, Western Sea Regional Fisheries Research Laboratory, Japan Sea Regional Fisheries Research Laboratory, Pelagic Fisheries Research Laboratory; National Research Institute of Aquaculture, National Research Institute of Fisheries Engineering Pearl Inspection Stations, Shimonoseki College of Fishery; Hokkaido Salmon and Trout Hatchery
      - Japan Marine Fishery Resource Research Center
  - Ministry of International Trade and Industry *
    - Agency of Industrial Science and Technology
      - Geological Survey of Japan
    - Agency of Natural Resources and Energy
  - Ministry of Transport *
    - Institute for Technical Research of Ships, Electronic Navigation Laboratory; Institute for Technical Research of Ports and Harbors
    - Meteorological Agency
    - Maritime Safety Agency
  - Ministry of Posts and Telecommunications *
    - Radio Research Laboratory
  - Ministry of Labor *
  - Ministry of Construction *
    - Public Works Research Institute, Building Research Institute
  - Marine Development Council (MDC) (Secretariat Science and Technology Agency)
  - Liaison Committee for the Promotion of Marine Science and Technology Development (Secretariat Science and Technology Agency)

Note *Ministries and agencies comprising the Liaison Committee for the Promotion of Marine Science and Technology Development

Marine Development by Private Sector

- Keidanren (Federation of Economic Organizations)
  - Committee on Oceanic Resources

Member companies and organizations include

Asahi Glass Co., Ltd/Idemitsu Kosan Co., Ltd/C Itoh & Co., Ltd/Ishikawajima-Harima Heavy Industries Co Ltd/Iwatani & Co., Ltd/Ube Industries, Ltd Ohbayashigumi, Ltd/Oki Electnc Industry Co., Ltd/The Overseas Economic Cooperation Fund Kajima Corporation Kawasaki Heavy Industries Ltd/Kawasaki Steel Corporation/Kawasno Corporation/Kyushu-Yamaguchi Federation of Economic Organizations/Kyowà Hakko Kogyo Co., Ltd./Kuraray Co., Ltd/Japan Light Metal Association/Kobe Steel, Ltd/International Engineering Consult Association/Komatsu Ltd/Sasebo Heavy Industries Co Ltd/Sankyu Inc./The Sanwa Bank, Ltd/Nippon Steel Corporation/The Shimizu Bank Co., Ltd Shimizu Construction Co., Ltd/Shinko Electric Co Ltd/Sumitomo Metal Industries Ltd Sumitomo Metal Mining Co., Ltd The Sumitomo Bank, Limited/Sumitomo Heavy Industries Lto/Sumitomo Corporation/The Cement Association of Japan/Japan National Oil Corporation/Petroleum Producers Association of Japan/Daicel Chemical Industries, Ltd/Taisei Corporation/Daido Steel Co., Ltd/Japan Fisheries Association/Dai Nippon Toryo Co., Ltd/Taiyo Fishery Co., Ltd/Japan Offshore Petroleum Development Association/Takenaka Komuten Co., Ltd/Teisan K.K./The Electric Chemical Industrial Co., Ltd/The Federation of Electnc Power Companies/Toda Construction Co. Ltd/The Tokai Bank, Limited/Tokyo Keiki Co., Ltd/Toshiba Corporation/Toyo Construction Co., Ltd./Toyo Rubber Industry Co., Ltd/Toyo Menka Kaisha Ltd/Toray Industries Inc./Nikko Electric Industry Co., Ltd./Nissan Construction Co., Ltd./Nissho Iwai Corporation/Nissin Electric Co., Ltd./JGC Corporation/Japan Petroleum Exploration Co., Ltd/The Japan Machinery Federation/Nippon Kinzoku Co., Ltd./Nippon Koei Co., Ltd./Nippon Kokan K.K./Japan Mining Industry Association/Japan Development & Construction Co., Ltd/The Japan Society of Industrial Machinery Manufacturers/Japan Resources Corporation/Nippon Suisan Kaisha Ltd/The Japan Steel Works, Ltd/Ocean Cable Co., Ltd./The Long-Term Credit Bank of Japan, Ltd/Nippon Electnc Co Ltd/Japan Electronic Industry Development Association/Japan Civil Engineering Contractors Association, Inc./Japan Management Association/Nippon Paint Co., Ltd/Japan Foreign Trade Counsel, Inc/Japan Radio Co Ltd/Nippon Oil & Fats Co Ltd/Nichimen Corporation/Hazama-Gumi, Ltd P.S. Concrete Co., Ltd/Hitachi, Ltd Hitachi Zosen Fujita Corporation/Bridgestone Tire Co Ltd/The Fuji Bank, Ltd./The Furukawa Electric Co., Ltd Howa Machinery, Ltd/Matsushita Communication Industrial Co., Ltd/Maruzen Oil Co., Ltd/Marubeni Corporation/Mitsui Mining and Smelting Co., Ltd/Mitsui Engineering & Shipbuilding Co., Ltd/Mitsui & Co Ltd/Mitsubishi Chemical Industries Ltd/Mitsubishi Metal Corporation/Mitsubishi Mining & Cement Co., Ltd/Mitsubishi Heavy Industries Ltd/Mitsubishi Corporation/The Mitsubishi Bank Ltd/Yamatake-Honeywell Co., Ltd/Yuasa Battery Co., Ltd/Yokohama Rubber Co., Ltd

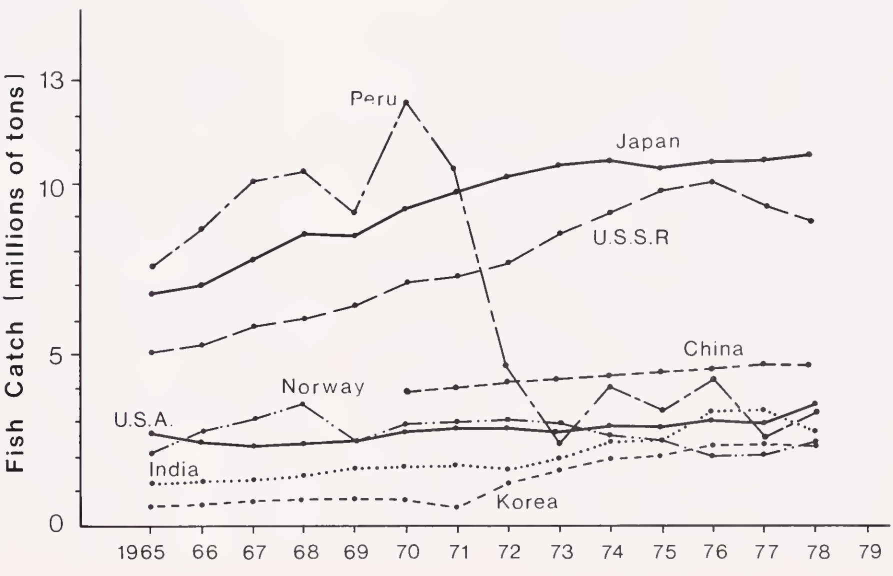
The Japanese Fisheries System

by Osamu Sato

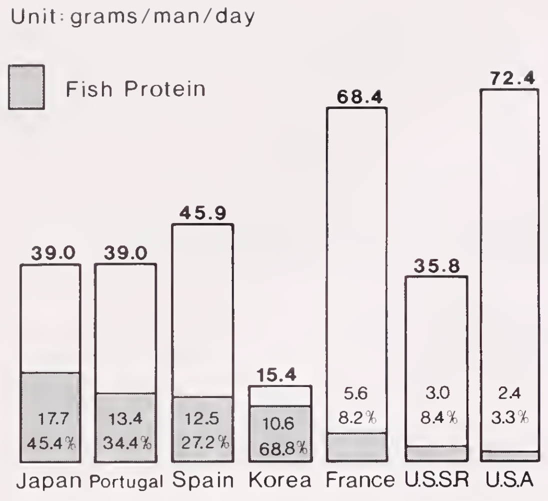
Since 1972, Japan has been the top fishery producer in the world. Of the animal protein consumed by the nation, 50 percent is from fish. Aside from consuming the largest volume of fishery products, the Japanese also consume the most extensive variety of fish, shellfish, and sea plants—fresh, salted, dried, pasted, and otherwise processed. But, like other nations, Japan has had to deal with a changing national and international scene. In this changing world, fishing and maritime transportation remain the two pillars of Japan's ocean policy. What changes have occurred, and how has the system conformed?

Modern Fisheries Regulation

Before the 19th century, the Japanese system of fishery regulation consisted principally of exclusive fishing sites granted by feudal lords to fishermen for the harvesting of rocky beach fishery resources, such as abalone, sea urchins, and seaweed; and for the common use of offshore fishery resources. During the 20th century, the promulgation of the National Fisheries Law laid the foundation for a fishery regulatory system by providing ordinances on fishery rights, fishermen's associations, and fishing limitations. The 1950s saw the establishment of the current Fisheries Law, aimed at overhauling the traditional methods of operation rooted in fishing villages, promoting integrated utilization of water resources and fishing productivity, and the democratization of the fishing industry through the operation of fishery control mechanisms supported by fishing operators. The Fisheries Law divides



Fish catches by major countries of the world. The total fishery production of the world is estimated at 70 million tons, out of which 15 percent, or approximately 10 million tons, is produced by Japan. (Source: FAO Yearbook of Fishery Statistics, and The Fisheries Agency [of Japan] Report for 1981)



World consumption of fishery products. The ratio of fish protein to total animal protein is largest in Korea and Japan. (Source: FAO Provisional Food Balance Sheets, and The Fisheries Agency [of Japan] Report for 1981)

fishery production into fishing by fishery right, licensed fishery, and free fishery.

Fishing by Fishery Right

The fishery right is the exclusive right to conduct certain types of fishing operations in a given water area under a permit from the prefectural governor. This right is considered equivalent to the real property right, except that the selling and buying of the right are subject to special regulations.

There are three broad categories of fishery rights: the *fixed net fishery right*, which allows fishing by emplacing fishing equipment in a designated area; the *demarcated fishery right*, which allows aquaculture in a designated area; and the *common fishery right*, which allows joint use of a designated area for fishery purposes. The common fishery right, however, is granted only to fishermen's associations composed of fishermen possessing certain qualifications. In granting the fishery right, the prefectural governor is required to gather comments from marine zone control committees (currently the Japanese shorelines are divided into 66 marine zones) composed of committee members and experts elected by fishermen, to conduct public hearings, and to gather comments from persons or parties whose interests might be affected by the grant. At the conclusion of this process the governor also is required to issue public notice of his intention to grant such a right. Further, under the law, the fishery right is granted only for a specified term, subject to renewal on a periodic basis. A common fishery right may be established in any area extending 6 kilometers from the Japanese coast, except for ports, harbors, and other special areas. There are some 3,000 fishermen's associations eligible for common fishery rights.

Licensed Fishery

There are two types of licensed fisheries: *designated fishery*, granted by the Minister of Agriculture, Forestry, and Fisheries; and *governor-licensed fishery*, granted by the governor of a prefecture or a municipality. The philosophy underlying licensed fishery is to impose a general prohibition of fishery in areas requiring protection of marine resources and control of fishery operations, or for any reason that is consistent with public interest, and to grant a waiver from the prohibition to operators whose fishery applications have been reviewed and approved by the local administration agency.

Designated Fishery. A license for designated fishery is required in situations where it is necessary to protect marine resources and where it is deemed appropriate to institute resource protection on a uniform basis. Such licenses are granted after the publication of public notices of information such as the number of vessels and vessel tonnage to be licensed. Presently there are 17 types of fisheries conducted under license, including offshore and high seas trawling by motorboats weighing 15 tons or more; long-lining, gill netting, and mothership bottom trawling in the North Sea; round-haul netting by vessels 40 tons or greater; whaling; high seas bonito and tuna fishing by vessels 80 tons or greater; salmon and trout long-lining by vessels 10 tons or greater; and mothership-based crabbing.

Governor-Licensed Fishery. This type of fishery can be licensed at each prefectural governor's discretion, by taking into consideration the state of the fishery in waters under his jurisdiction. A wide variety of fishing activities, including gill netting and octopus potting, are eligible for the governor's license. However, the law requires that four types of activities, including small-scale bottom trawling requiring interprefectural controls, must be regulated on a uniform basis.

Free Fishery

In principle, those fishing activities that are not defined by the fishery right or licensed fishery regulations can be conducted freely.

Fishing Ports and Boats

Fishing ports serving as bases for fishing-vessel activities and sites for marine product distribution are regulated separately from commercial ports. There are some 3,000 fishing ports in Japan, with fishing port zones extending along 6,000 kilometers, representing 18 percent of the total length of the Japanese coast. The majority of the ports fall into "Category 1"—for use by local fishermen. "Category 2" ports are those utilized by activities that are greater than local but less than national in scope. "Category 3" ports are those engaged in nationwide fishing activities. "Category 4" ports are located in remote areas and islands and serve more or less as emergency storm shelters.

There are nearly 400,000 fishing vessels operating from Japanese ports, with the majority less than 5 tons in size. The remaining vessels extend upward in size to the 1,000-ton and greater range. Many of the larger ships are modern, with automated features. (The above figures are exclusive of inland-water fishing boats.)

Fishery Production

Exclusive of whaling, Japanese fishery catches fall into five categories: high seas fishery, offshore fishery, inshore fishery, inland surface fishery, and marine surface aquaculture. Table 1 shows the production volumes from these activities during the January–December 1983 period in tonnage and monetary values of catches. Figure 1 shows changes in catches for these categories during the 1975–1983 period.

High Seas Fishery. The high seas fishery involves large-scale fishing operations extending for long periods of time. Most of the designated fisheries and some of the governor-licensed fisheries fall into this category. The principal forms of high seas fishery are deep-sea bottom trawling (skate, codfish, flatfish, prawns, and others); large-scale round-haul netting (bonito and tuna); mothership-based salmon and trout gill netting; tanner-crabbing in the northern Pacific Ocean; pole-and-line fishing for pelagic bonito; squid fishing in the New Zealand fishing zone; tuna long-lining; and the long-line fishery conducted in the Atlantic Ocean. Many of these types of fishery are conducted within the 200-mile limits of other nations, and catches are subject to quotas that are negotiated between Japan and affected countries. Despite the decline in negotiated quotas over the recent years, the total catch in pelagic fisheries has remained approximately constant because of increases in tuna and bonito fishing in the open seas.

Offshore Fishery. The offshore fishery is ocean surface fishing using vessels of 10 tons or greater, exclusive of pelagic fishing. Most of the offshore fishing is comprised of governor-licensed fishing, and includes offshore bottom trawling, large- and medium-scale round-haul fishing, purse seining, saury stick-held dip netting, coastal squid fishing, coastal bonito pole-and-line fishing, and coastal tuna long-lining. Rich harvests of sardines have contributed to increases in the catch for this category of fishery.

Table 1. Catches by fishery category for 1983, by tonnage and value.

Fishery category	Tonnage (per 1,000 tons)	%	Value (per 100 million yen)	%
High Seas fishing	2,127	17.7	6,389	22.0
Offshore fishing	6,433	53.8	8,202	28.3
Coastal fishing	2,137	17.8	7,456	25.7
Seawater surface aquaculture	1,060	8.9	5,186	17.8
Inland surface water fishing	211	1.8	1,793	6.2
TOTALS	11,967	100.0	29,032	100.0

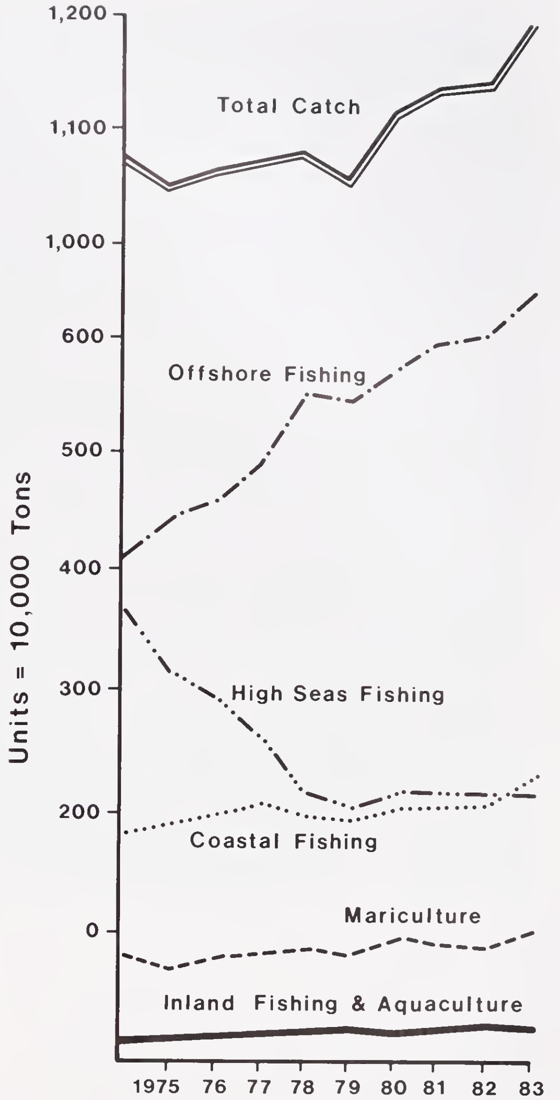
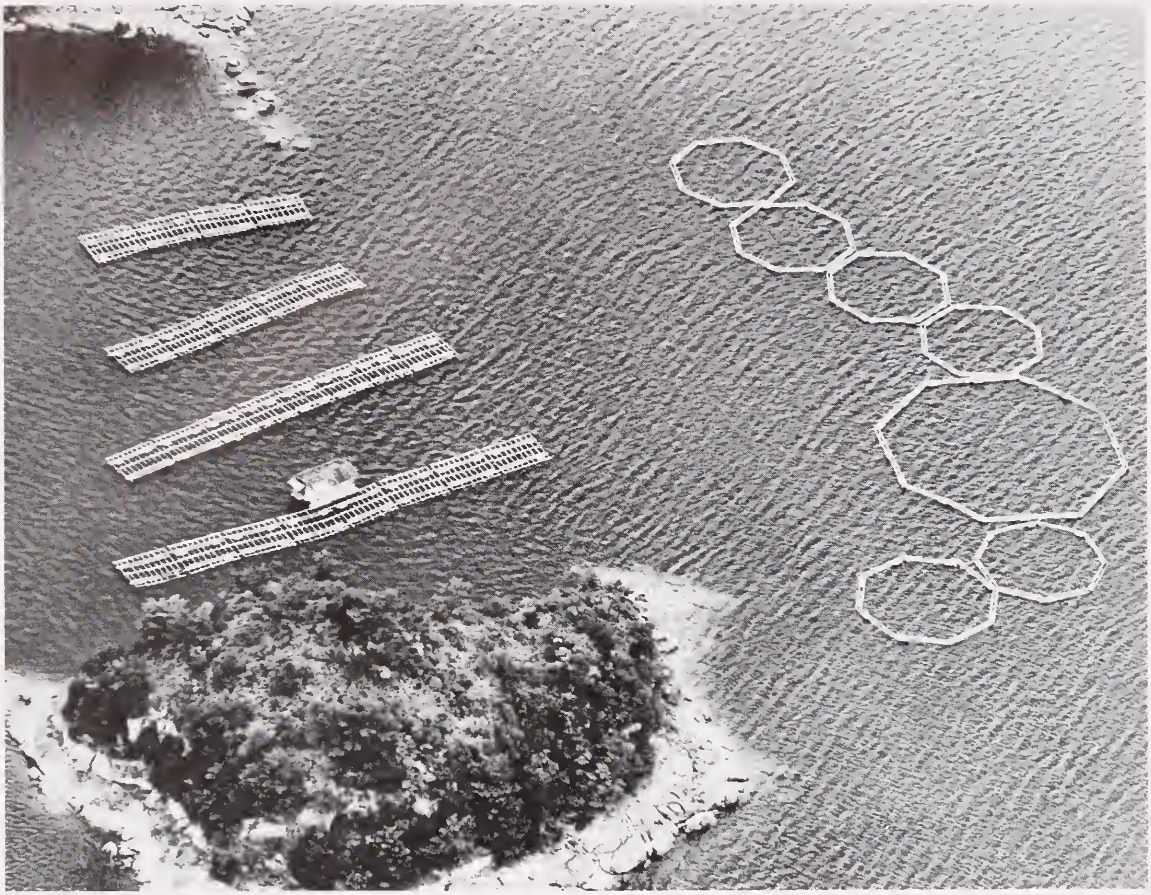


Figure 1. Catch by fishery category, 1975 to 1983.

Coastal Fishery. The coastal fishery includes fishing operations using motorless boats or vessels under 10 tons, set netting, drag netting, and fishing without use of a vessel. It consists of fishery by fishery right, except for the fishery by demarcation fishery right, and part of the governor-licensed fishery. In terms of fishing operations, the term refers to a fishery conducted within an area that can be covered in a day's trip by boat. The volume of fishing under this category has been 60,000 tons by fishing without use of a fishing boat, 1,560,000 tons by boat fishing, and 570,000 tons by set netting and drag netting. In monetary values these catches represent Y17.5 billion (US$110 million), Y555.1 billion (US$3.5 billion), and Y164.9 billion (US$1 billion), respectively, with an average of approximately 300 yen (US$2.00) per kilogram in all cases.



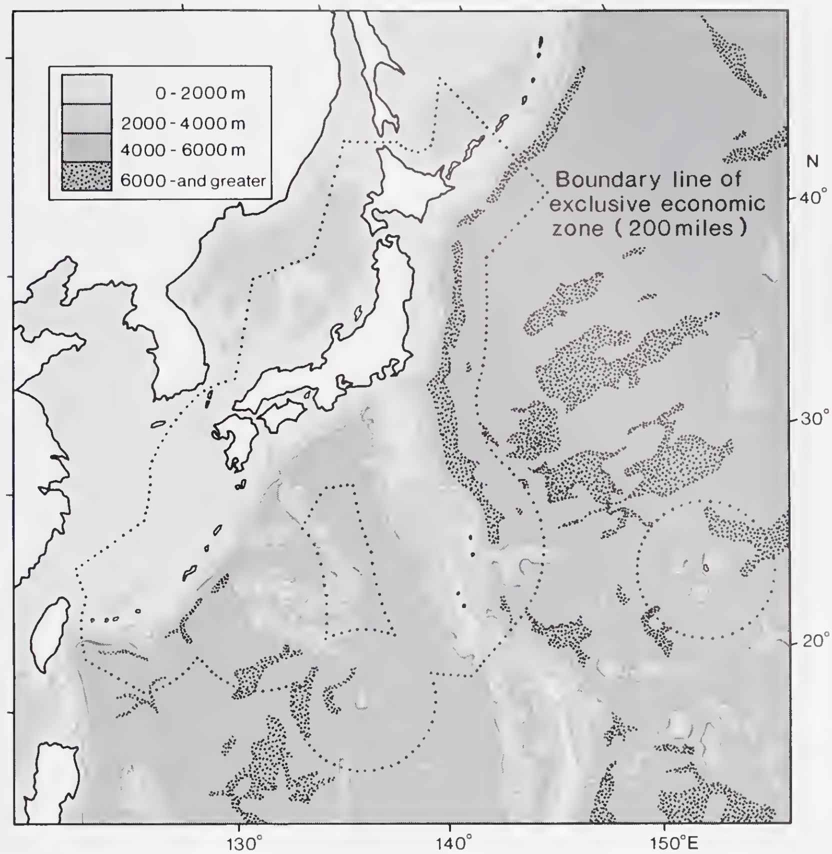
Oyster rafts off the island of Kyushu (Photo by G. Gerster/Photo Researchers, Inc.)

Inland Water Surface Fishery. The inland water surface fishery (includes freshwater aquaculture) is the fishery conducted on lakes, rivers, and other freshwater bodies by small fishing boats. Principal species caught are salmon, trout, *ayu*, carp, crucian carp, eel, and shellfish. About half of the catches are of corbicula clams. More than 90 percent of freshwater aquaculture consists of eel, rainbow trout, *ayu*, and carp, with *tilapia* and soft-shelled turtles on the rise in recent years.

Marine Aquaculture. The bulk of the marine aquaculture is conducted by operators with demarcation fishery rights, raising yellowtail (a type of jack), sea bream, jack mackerel, flounder, prawns, oysters, scallops, seaweed, wakame seaweed (*Undaria*), kelp, and pearls. In a recent development, increasing numbers of companies have been conducting aquaculture by pumping seawater into land-based facilities. In flounder culture, there has been a trend toward specialization, with some companies supplying fertilized eggs and others purchasing these eggs and rearing them into fingerlings 2 to 3 centimeters in size. This trend has taken hold sufficiently so that aquaculture companies can now be selective as to which of the fingerling growers are capable of supplying the highest quality stock. Thus, it appears that in the culture of high-priced fish, more and more private companies will be supplanting government-funded operations in supplying fingerlings to fish growers, thereby spurring further advance in the Japanese seawater aquaculture industry.

The change in the global ocean regime has resulted in new emphasis on Japan's national fisheries. Traditionally, Japan stood clearly in favor of narrow coastal state sovereignty and broad freedoms on the high seas—largely shaped by Japan's extensive dependence on ocean space and ocean resources. As a result, there was a postwar trend away from coastal fisheries in favor of offshore and distant-water fisheries. In recent decades, the world, joined by Japan, has moved decisively toward coastal oceans—staking national claims to broad fishery zones extending out (most often) 200 miles from the nation's shores. With this global change, Japan's former trend has been reversed, and the relative importance of coastal and near-shore fisheries is increasing.

To increase productivity within its own 200-mile zone, Japan has been supporting some 850 fishing-ground creation projects, including the erection of artificial fish reefs, at a cost of over 35 billion yen (US$218 million) in public funding. This



The fishing waters off Japan showing the boundary line of the Exclusive Economic Zone (200 nautical miles).

program will increase in size in the future. Additionally, efforts are being made to create and expand high-quality fishing grounds through the release of cultured fingerlings and other means. Another priority area is the promotion of culture-based fishery and resource conservation fishery in combination with the education of our fishing population.

Fishery Education

The beginning of higher education in fishery science in Japan can be traced to a course given by Dr. John C. Cutter at the Sapporo Agricultural School in 1879. The first institution for fishery education came from the establishment of a department of fishery science in the Tokyo School of Agriculture and Forestry in 1887. Subsequently, the Ministry of Agriculture and Commerce founded a Fisheries Institute in 1897, and the Ministry of Education established departments of fishery science in the Tohoku Imperial University Faculty of Agriculture and in the Tokyo Imperial University Faculty of Agriculture enabling each of these institutions to conduct independent and systematic programs for fisheries education. These institutions have continued, and they are now known, respectively, as the Tokyo Fisheries University; Hokkaido University Faculty of Fisheries Science; and the University of Tokyo Faculty of Agriculture, Department of Fisheries Science. The first intermediate-level program of fisheries education was established in Fukui Prefecture in 1899. Subsequently, similar programs were established in various prefectures and municipalities. Presently most of the prefectures situated in coastal locations have fisheries high schools or regular high schools offering one or more courses in fisheries science. From the very beginning, fisheries education institutes have been provided with training ships and seaside laboratories. Master's and doctorate-level programs started in 1953 with the establishment of graduate school departments of fisheries science. These programs have continued to the present.

Intermediate-Level Fisheries Education. Most of the educational programs in Japan are under the direct supervision of the Ministry of Education. Basically, the Japanese system of education is a 6-3-3-4 system, where pupils enter grade school at the age of 6, advancing to intermediate school after 6 years of instruction. Nine years of schooling is compulsory. However, the majority of students graduating from intermediate schools go on to either regular high schools, or vocational schools in industry, commerce, or fisheries. All of the 40 Japanese fisheries high schools are public schools, the fewest among all types of vocational schools in number. They offer courses in fisheries and fishery manufacturing. In addition, they offer one or more programs in aquaculture, radio communication, marine engineering, and management. They also have fisheries training ships and conduct practical

Hokkaido and Alaska Universities

In January of this year, Mikio Arie, President of Hokkaido University, and Donald O'Dowd, President of the University of Alaska, signed an agreement providing for cooperation and an exchange of faculty and students between the two institutions. This followed a similar fisheries research and exchange agreement signed last July between the Dean of the Faculty of Fisheries, Hokkaido University, and the College of Fisheries and Science, University of Alaska at Juneau. These two actions served to formalize the long-standing relationships already in existence.

A common bond exists in that these two northern universities both have a strong dedication to research in oceanography and the fish populations of the northern North Pacific and the Bering Sea. Fishermen from Japan, the Soviet Union, and the United States have long fished the eastern Bering Sea and the Gulf of Alaska—often exporting the same stocks of salmon, halibut, and herring.

During the 1950s, both Japan and the Soviet Union launched large high seas oceanographic and fisheries investigations. In 1956, the Faculty of Fisheries dispatched the 1,120 gross ton T/V Oshoro-maru *to the eastern Bering Sea and the Gulf of Alaska. Its mission was to train cadets and conduct research on the migration of salmon on the high seas. A fundamental aspect of that research was the effect of water body masses, as identified by temperature and salinity, on the aggregation and movement of salmon.*

At that time, the University of Alaska's oceanographic work was confined to inside waters and the Arctic Ocean where large vessels were not needed. The fisheries program also was small and confined to teaching fishery management, biology, and doing research on

Oshoru-maru in Alaska.

freshwater fish.

In 1965, the University of Alaska's Institute of Marine Science (IMS) acquired the R. V. Acona *and was able to mount a high seas oceanographic research program. Although the* Oshoro-maru *had conducted annual cruises in the eastern Bering Sea and Gulf of Alaska on an annual basis, it was not until 1964 that she made her first Alaskan port call at Kodiak. Soon after, scientists from both institutions began meeting informally each year when the* Oshoro-maru *called at an Alaska port.*

Early discussions noted some sharp philosophical differences in institutional approach to ocean science and fisheries. In the United States, fisheries science and oceanography were distinctly different sciences. Seldom did the scientist in one discipline have more than a passing interest in the other.

The opposite was true at Hokkaido University. Oceanography was integral to fisheries science.

training in fishery operations and navigation. There are also 11 regular high schools offering fishery-related courses in fishery operations, fishery food processing, management, aquaculture, radio communication, and oceanography.

Advanced Education in Fishery Science. Approximately half of the high school graduates in Japan go on to four-year colleges, each consisting of one or more faculties. Basically, there are three types of undergraduate colleges offering training in fisheries science: those supporting a fisheries science department as one of the several departments existing in a faculty of agriculture; those having a fisheries science faculty containing either two or more fisheries departments or a single department offering two or more courses in fisheries science; and those having fisheries-related departments within a non-agriculture faculty. Table 2 shows numbers of faculty and students in these colleges as of 1986. The number of undergraduate colleges containing fisheries departments represents 31 percent of the total number of undergraduate colleges in agriculture and fisheries. The number of students enrolled in fisheries schools represents 12 percent of all students in the agricultural and fishery schools; it also represents 0.45 percent of the whole public and private college student population in Japan.

Post-Graduate Education consists of a two-year master's program and a five-year doctorate program. Most programs are offered as a continuation of undergraduate education. Some

in Cooperative Fisheries Studies

The field of fisheries oceanography was developed in Japan. Their fisheries faculty is composed of departments of biology and aquaculture, chemistry, food science, and fishing science. With the exception of food science, each department places heavy emphasis on oceanography. Simply stated, the goal is the efficient production, harvest, and processing of food from the sea.

Although their goals may have been different, it was apparent that the scientists at each institution had closely related research interests. These interests led to a number of international symposia and cooperative projects. In 1972, the Faculty of Fisheries hosted the International Symposium for Bering Sea Study in Hakodate, Japan. A second symposium was convened by IMS at Fairbanks, Alaska, in October, 1974.

In 1975, the University of Alaska initiated a research and education program in fisheries oceanography within the IMS. Tsuneo Nishiyama, an instructor of marine fisheries ecology, and a Bering Sea veteran at the Faculty of Fisheries, was chosen to start the program. Nishiyama has continued his activities in the Bering Sea, guided a number of graduate students, and periodically invited doctor's degree candidates from the Faculty of Fisheries to IMS for research in Alaska before they returned to their own institution to take their degrees.

A large research program, Processes and Resources of the Bering Sea (PROBES) was initiated in 1976. This was a multidisciplinary project involving a number of academic institutions from the United States and Japan. Major research contributions were made by Hokkaido University and the University of Alaska. The research concentrated on gaining an understanding of the oceanic processes of the middle and outer continental shelf, which make the area one of very high productivity.

PROBES was completed in 1983 and was immediately succeeded by another research program—Inner Shelf Transfer and Recycling (ISHTAR). The mission is similar to PROBES but will concentrate on the inner and northern Bering Sea shelf. During the summer of 1986, scientists from the two institutions conducted joint research on the ISHTAR project. IMS, Faculty of Fisheries, and University of Washington scientists were on board the Oshoro-maru. *The University of Alaska's* Alpha Helix *carried University of Alaska, University of Texas, and University of Archus, Denmark, scientists. Similar work is scheduled for this summer.*

The cooperation and exchange between the two institutions also regularly includes the mutual exchange of students involved in graduate studies, visiting faculty, and the presentation of scientific papers and seminars.

The cooperative effort between the universities has not been limited to marine science. Other efforts range from anthropology to geophysics. Both have a number of other international arrangements.

There are many long-term benefits that can occur through international cooperation. One is that greater human resources are available to research important ocean processes. Another is an increase in cultural understanding. The latter benefit is especially important to Japan.

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universities, however, offer an independent three-year doctorate program, which students can pursue after completing a master's program.

Many universities offering training in fisheries science are equipped with seaside laboratories, food-processing practice factories, and lakeside laboratories. Seven universities have training and research vessels. There are 12 training and research vessels nationwide, of which 4 vessels are over 1,000 tons in size, 4 are in the 800-ton class, and 4 are between 100 and 350 tons. Four fisheries science faculties, each of which has 1,000-ton and 800-ton ships, offer a special one-year marine crew training program (license course) as an adjunct to a 4-year undergraduate program, which enables students to acquire licenses as ship navigation officers. The five nationally-funded fisheries science undergraduate colleges offer courses centered on fisheries science, aquaculture, and food processing. In addition, they offer courses in environmental engineering, fisheries chemistry, marine resources, and fisheries management. Universities that have fisheries science departments within agriculture faculties offer courses in biology and chemistry as part of fisheries training.

Training Programs Outside the Jurisdiction of the Ministry of Education. There is one fisheries college run by the Ministry of Agriculture, Forestry, and Fisheries. Similar to regular universities, this college accepts students who have completed their high school education, and offers roughly the same level of education as national university fishery

Table 2. Undergraduate and research programs in universities and graduate schools offering training in the fishery sciences, and numbers of students.

Program name	Number of programs: National universities	Number of programs: Private schools	Total	Number of students: National universities	Number of students: Private schools	Total
Department of Agriculture Fisheries Program	7	1	8	157	100	257
Department of Agriculture Research Program, Specialization in Fisheries						
Master's programs	7	0	7	63	0	63
Doctoral programs	6	0	6	25	0	25
Department of Fisheries Science	5	1	6	860	160	1,020
Department of Fishery Science, Fishery Research Program,						
Master's curriculum	5	1	6	208	6	214
Doctoral curriculum	1	1	2	28	3	31
Agricultural departments	1	2	3	110	300	410
Agricultural research programs, in biological productivity science						
Master's curriculum	1	0	1	25	0	25
Doctoral curriculum	1	0	1	5	0	5

science faculties, with about the same number of departments and teaching personnel. Although it does not have a graduate division, it offers a program in marine engineering. Equipped with two large vessels, it provides special courses in navigation-officer and marine-engineering training as part of ship's crew education, and conducts navigation training. On a local level, the municipalities and prefectures situated in coastal areas have fisheries improvement, information dissemination, and guidance centers for the continuing education of fishermen. About 400 instructors provide day-to-day training that includes the introduction of research results achieved at national marine research centers and prefectural marine laboratories. In addition, Hokkaido and other prefectures have fisheries training centers for providing regularly scheduled training courses in fishing technology fundamentals, radio communication, and small-vessel operation intended for fishermen. Also, there are two fishermen's cooperative association schools designed to provide training on fishing household management and the management of fishermen's cooperative associations.

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The Salmon Fishery

by Takeji Fujii, and Seikichi Mishima

Japanese fishermen first harvested salmon swimming upstream in rivers of the [Russian] Sakhalin peninsula situated at the northern tip of the Japanese archipelago. In 1752, the feudal clan of Matsumae had three fishing bases in Sakhalin. Subsequently, in 1892, permission was granted to use a site in the Amur area (to the west, on the Russian mainland) for the processing of fish products. Also, permission was granted, under Russian ordinance, to maintain a number of fishery operations jointly with the Russians.

In a gradually modernizing Japan, systematic fishery development started in about the year 1900, with Japanese nationals working in the salmon fishery near the largely unexplored Siberian coast. However, the expansion of the Russian fishing industry eventually forced Japan to retreat from the Russian mainland and Sakhalin.

In 1927, to circumvent Russian fishery regulations, the Japanese devised and successfully implemented a technique of offshore salmon fishing based on the combined operations of a mothership and long-liner boats. This technique was used until about 1943 along the Russian coast in combination with set net fishing. The coastal set net fishery, however, began to decline in 1933, producing only 60 percent of the catch of the previous year. The offshore fishery, on the other

Salmon catches being hauled into a fish market (Courtesy of Hokkaido Salmon Hatchery)

hand, increased. After World War II, to alleviate the food supply crisis in Japan, small-scale salmon fishing was conducted during May and June along the Pacific coast of Hokkaido, with a gradual expansion of long-line fishing to deeper seas.

The signing of a fishery treaty in 1952 between Japan, the United States, and Canada allowed the Japanese to conduct mothership and land-based offshore salmon fisheries in the Pacific Ocean and related seas to the west of longitude 175 degrees West. Under the treaty, research was conducted for the purpose of ensuring sustained production of salmon resources, including ecological and offshore distribution studies of species originating on the Asian and American continents. After that, the Japanese salmon industry based on offshore fishing gradually expanded in scale. By contrast, the catch of coastal salmon fishing in the Soviet Union continued to decline. On the grounds that the Japanese offshore salmon fishing operations in that area could have a severe adverse impact on the reproduction of fish resources, significant limitations were imposed on those operations. The trend extended further in 1956 when the Japan-USSR Fisheries Treaty was signed. The objective of ensuring maximum sustainable yield resulted in a further decline in the volume of fishery production.

Although salmon fishing in the northern Pacific areas continued, in 1978 a catch quota of 42,500 tons, a 31 percent cut from the previous year, was agreed to. More recently, the enactment of the USSR 200-mile fishery management zone, simultaneous with the implementation of the U.S. Fisheries Management Law in 1979, had a further impact on Japan's fishing operations in northern Pacific areas. By 1986, the catch had declined to 24,500 tons.

Salmon and Trout of Japanese Origin

During the latter half of the 19th century, the Japanese salmon resource sustained by natural breeding had an estimated population of 7 million fish (25,000 tons). This declined rapidly, amounting to some 4 million fish by 1970. Early on, efforts were made to enhance the natural stocks of salmon by means of artificial salmon hatching and release technology.

The first artificial hatching and release of chum salmon were accomplished in 1880, raising considerable interest in the commercial breeding of salmon of Japanese origin in the Tohoku and Hokkaido areas. Until recent years, the rate of reproduction from artificial breeding continued to be low. However, a variety of technological advances, and experience gained through years of effort, produced improvements in the fish return rate. According to unpublished 1985 data compiled by the Hokkaido Salmon/Trout Hatchery, 1975 saw a return of 1.6 million fish (57,000 tons), which increased to more than 30 million fish (Figure 1), producing a return rate of 2.4 percent compared to a rate under 1.0 percent in earlier years.

Accomplishments in the following areas have contributed to these favorable results: 1) ensuring an adequate stock of parent fish, 2) improvements in artificial hatching technology, 3) prevention of fish diseases, 4) improvements in fish rearing techniques, 5) judicious choice of release timing, and 6) appropriate control of the number of fish released at a time. Additionally, it appears that when they are allowed to descend from the river of their birth to the ocean in numbers not exceeding the carrying capacity of the coastal areas in which they make their habitat, the survival of the fingerlings is enhanced. This also contributes to increases in their return rate.

Adding to this improving picture, systematic efforts are currently being undertaken in the artificial hatching and release of the cherry salmon, a member of the salmon family unique to Asia, from the rivers discharging into the Japan Sea. Also, the artificial breeding of pink salmon, currently being attempted in some rivers located in northeastern Hokkaido, is expected to gradually increase in scale. Along with the progress in efforts to increase the quantity of the resource, quality is also being examined—advances in biotechnology are making it possible to select the sex of fish offspring by chromosome manipulation, and to breed artificially enlarged fish.

An important task lying ahead of us is to utilize these various possibilities within the structure of existing ecosystems, without causing an undue or unwanted disruption in the self-perpetuating system comprised of the environment and its living organisms.

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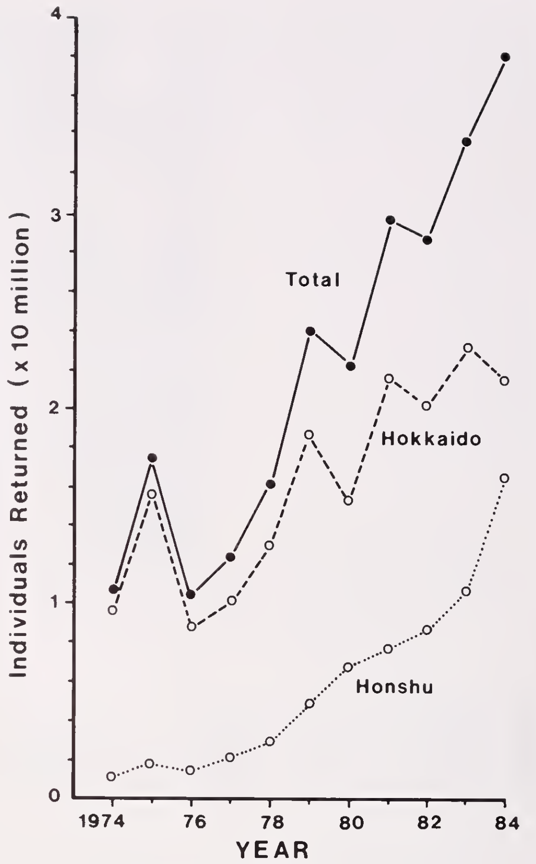
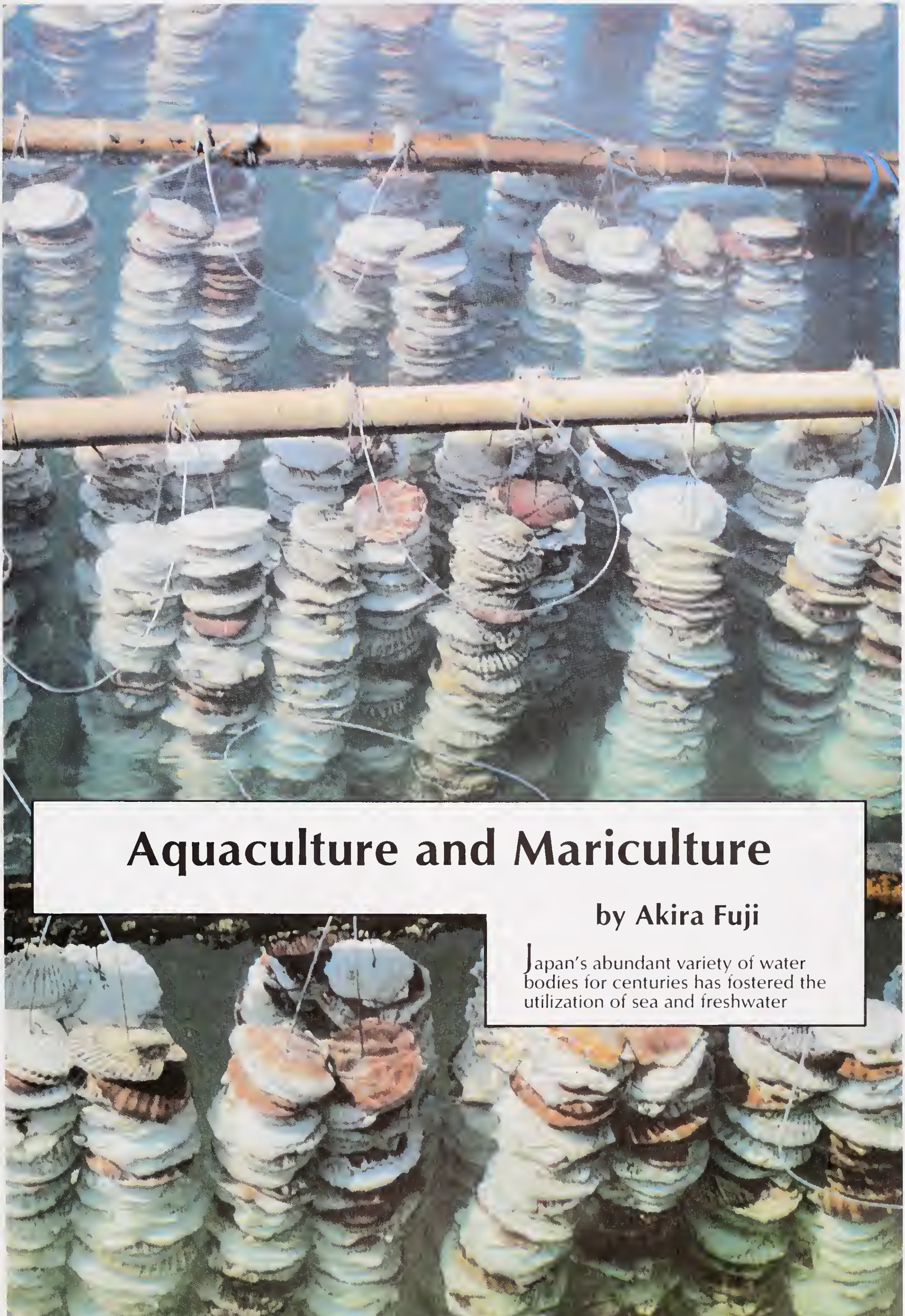


Figure 1. Returns of Japanese chum salmon.

Salmon fingerlings ready for release (Courtesy of Hokkaido Salmon Hatchery)



Aquaculture and Mariculture

by Akira Fuji

Japan's abundant variety of water bodies for centuries has fostered the utilization of sea and freshwater food supplies. Aquaculture, the farming and husbandry of such supplies, has developed over the years from a side activity of farmers into an industry in its own right. In the last 30 years, innovations in techniques and facilities have transformed it into a successful and productive enterprise. It now accounts for 10 percent of the total fisheries yield, and in 1984 it netted an income of 676.6 billion yen (US$4.2 billion) (Figure 1).

Aquaculture aims to optimize the number of individuals of a given species that can grow to a commercial product within a defined aquatic area. It achieves this by controlling environmental elements and the life history of the organisms. In Japan, three categories of aquaculture—stocking, feeding, and sowing—represent different approaches to this final goal.

Aquaculture without feeding (stocking type), requires the establishment of a settling area for the spores or seeds of the organism to be grown, but demands no food input from the culturist. The organism drifts or is introduced to the settling area, and attaches itself to the supports provided—nets, empty shells, or bamboo stalks, depending on the species. It then feeds on nutrients and plankton in the water flowing through the area, and thus grows to harvestable size. This culture method is used for seaweed as well as scallops and oysters.

Aquaculture with feeding, the second major category, applies to the cultivation of all fresh water and marine bony fish. The organisms are confined in ponds or specifically-designed nets, and fed formulated preparations until they reach commercial size. Aquaculture by this second method requires artificial "seeding": fingerlings or fry collected in the wild are used as the starting stock in the holding areas. Although culturists have been able to rear seeds for certain species, many fish still require field collection of larval stages.

Culture-based fisheries ("sowing type") is a compromise between the first two methods. Natural fishing grounds are artificially seeded with field-collected or hatchery-reared seedlings, but the organisms are not fed by the culturist. Also, no special substrates are provided to promote growth. This method is successfully employed in scallop culture, and is still common for oysters in some areas.

All three techniques have been applied to the culture of both marine and fresh water species in Japan.

Mariculture

Both mariculture, the culture of marine species, and freshwater aquaculture are practiced in Japan, but mariculture is by far the more productive of the two industries. Its yield has increased about seven fold over the last 30 years. In 1984, it accounted for 92 percent of the total aquaculture yield. Mariculture employs all three categories of aquacultural techniques, since it involves shellfish and algae as well as finfish.

A shellfish, the Japanese oyster *Crassostrea gigas*, and a red alga called "Nori" (*Porphyra* species) have been cultivated in Japan since the 1700s, and have been the major products of mariculture up to the present. New species introduced in 1960–70 account for the recent marked increase in maricultural yield. The species include two fish, the yellowtail jack (*Seriola quinqueradiata*) and the red sea bream (*Pagrus major*); two types of brown algae, "Wakame," (*Undaria pinnatifida*), and "Konbu," (*Laminaria* species); and the scallop, (*Patinopecten yessoensis*). Money earned by mariculture of these seven organisms contributed about 77 percent of the entire income from Japanese mariculture production in 1984.

Figure 1. Annual production of total fisheries and aquaculture.

Innovations in all three aquaculture categories for marine species have been key in increasing harvest and income. The establishment of techniques for the production of large amounts of artificial hatchlings in 1975 resulted in a rapid increase in red sea bream yield; similarly, the development of the floating net cage culture method in 1965 markedly incremented the yield of yellowtail; and hanging methods in oyster farming have made it one of the most successful examples of aquaculture.

Aquaculture with feeding is used to grow yellowtail and bream. Fingerlings, hatchery-reared for bream but collected in the wild for yellowtail, are cultured to an initial stage in holding tanks. They are then released into net cages until they reach commercial size. A floating net cage (Figure 2) permits water flow through all of its surfaces. The resulting areation and oxygen availability allows the stocking of larger numbers of fish per unit area than would be possible in embayments or holding ponds. Higher productivity is thus obtained. The technique is now the primary method of yellowtail cultivation, and in 1984 yielded a catch 3.7 times that of the wild fish.

Scallop culture can involve stocking or sowing aquaculture. Either category requires three basic operations: collection of larvae (spat) in the wild; intermediate culture of spat; and finally,

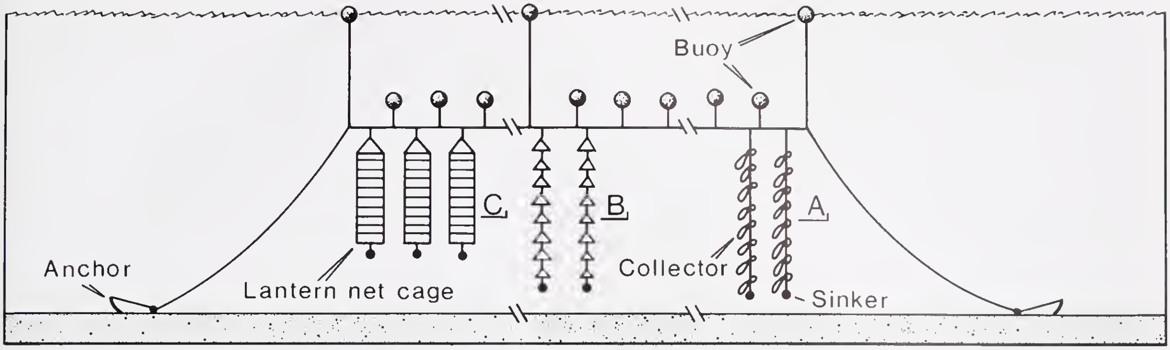


Figure 3. The three stages of scallop culture: A) spat are gathered in seed collectors—net bags filled with cedar twigs, B) collected spat grow to intermediate size inside pearl nets, and C) scallops are hung in lantern net cages where they grow to market size.

culture of the scallop to the commercial product by hanging or sowing. Figure 3 shows how the three stages can be operated simultaneously in a culture area. In hanging cultures, intermediate scallop seeds are placed in special "lantern nets," which are suspended from a long-line set in the water. In the sowing culture method, the spats are literally sown on selected harvesting bottoms, from which they are collected 2 to 4 years later. Annual yield from both types of cultivation has been 200,000 tons in recent years.

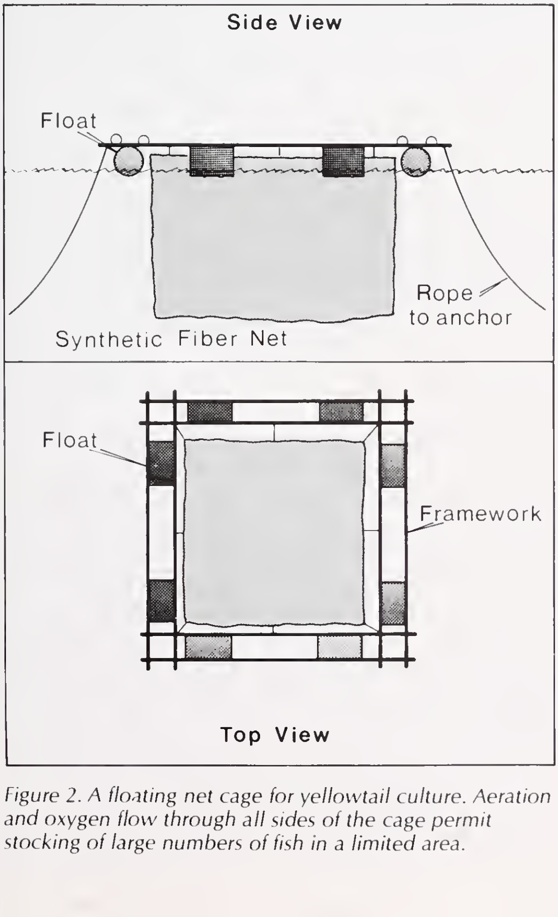


Figure 2. A floating net cage for yellowtail culture. Aeration and oxygen flow through all sides of the cage permit stocking of large numbers of fish in a limited area.

Oyster cultivation follows a pattern similar to that of the scallop. Seeds are obtained from the wild through the use of collectors. These consist of oyster or scallop shells ("culches") strung on a metal wire and hung vertically in the water. Seeds attach to these, and are grown to market size by further hanging of the strings of culches off racks, rafts, or long-lines (see Figure 4). The three-dimensional nature of the hanging method has permitted a remarkable increase in oyster productivity per unit area. The present industry has become stable at a yield of 250,000 tons per year in live weight.

Nori, which provides the most abundant seaweed harvest, is cultured through the use of several recently-developed techniques. Nets laid horizontally in the sea are sown with artificially-grown spores. These attach to the twine, develop into germlings, and eventually grow into fronds. The harvested fronds are dried and processed mechanically for market. Artificial spore cultivation and mechanization of the processing operation have permitted a rapid increase in *nori* production. Annual yield in 1984 reached as high as 400,000 tons in wet weight.

Freshwater Culture

The development of freshwater aquaculture has been quite slow compared to that of mariculture, due perhaps to the Japanese preference for marine fish over freshwater fish. Nonetheless, freshwater culture yields have similarly benefited from culturing improvements and introduction of new species, and income from the industry was 123.3 billion yen in 1984 (US$780 million). Four types of fish—rainbow trout, (*Salmo gairdneri*); a salmonoid fish called *ayu*, (*Plecoglossus altivelis*); common carp, (*Cyprinus carpio*); and eel, (*Anguilla* species)—accounted for 91 percent of the entire earnings from freshwater culture in 1984. All are grown by variations on feeding aquaculture.

Eel, the most commonly eaten freshwater fish, is the species yielding the largest income. Its traditional consumption on special Japanese holidays accounts for its popularity and its extraordinarily high market price. The high value of

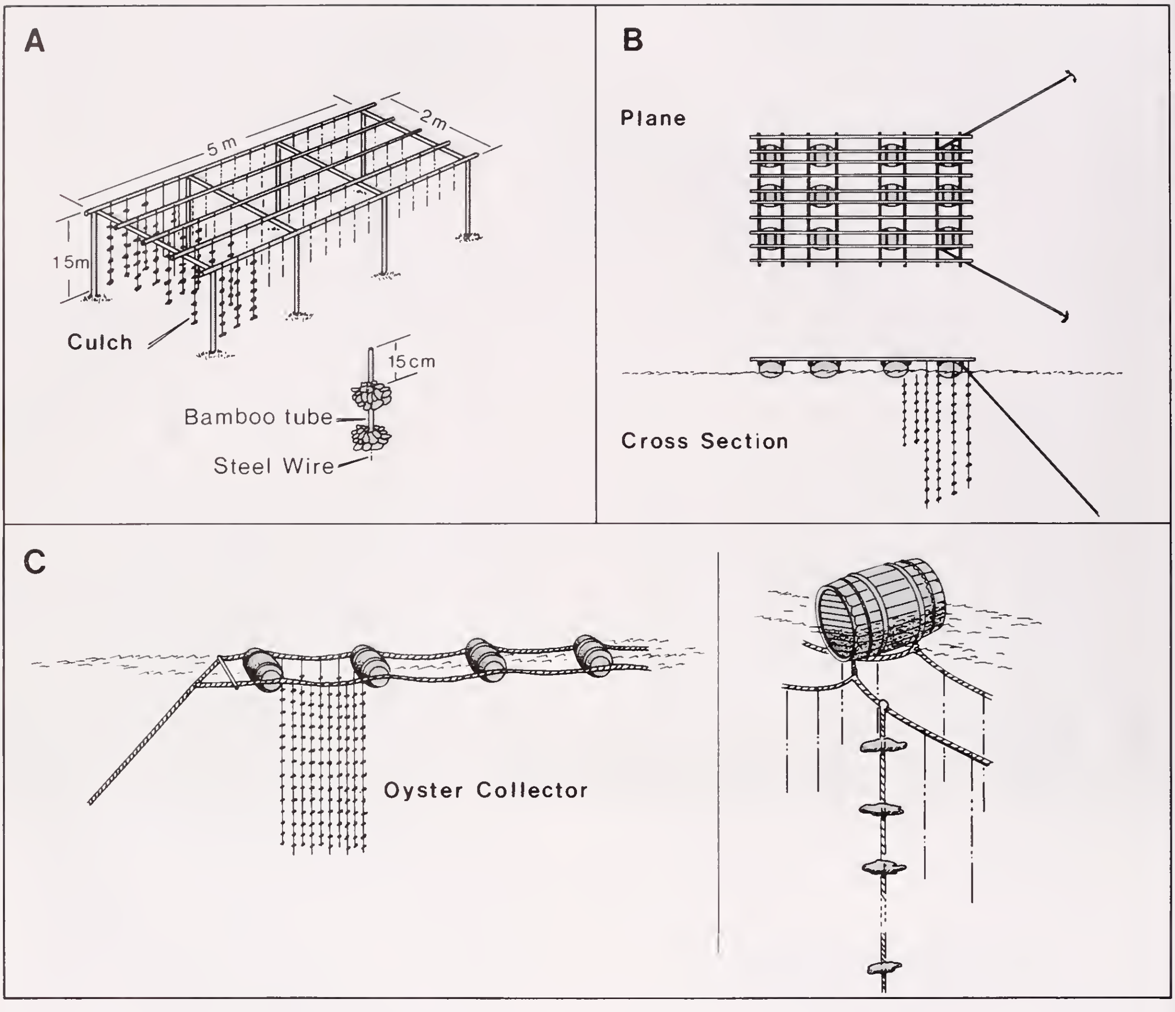


Figure 4. Different hanging methods for oyster culture: A) rack method—culches with attached oyster seeds are hung on a rack fixed to the seabed, B) raft method (the most employed)—strings of culches are hung on a cedar or bamboo raft, C) long-line method (can be used in open and deep waters)—the culches are hung on long lines kept afloat by buoys.

the fish has encouraged improvements in rearing facilities. In recent years, the outdoor still-water ponds that were used for eel culture have been replaced by indoor tanks supplied with heating and water circulating systems. Elvers for seeding the tanks, however, must still be collected in the wild.

Several other fish species are commonly grown. Like the eel culture, carp culture has progressed from the use of ordinary ponds or rice paddies as holding tanks to the employment of more sophisticated running-water ponds. In 1984, 21,071 tons were produced by culture. Rainbow trout culture began in 1877, when 10,000 eggs were imported from California. After the war, culture was sustained by a U.S. market that encouraged export, and which has permitted its steady increase to the present. The most recent addition to freshwater aquaculture is *ayu*. Commercial culture of this fish began after the war, and recent catches have yielded some 15,000 tons per year. It is now distributed from central to southern Japan.

Future Research

Many problems hinder further expansion of the aquaculture industry in Japan. First, culture of major species, with the exception of seaweeds, still depends on natural seeds collected from the wild. A stable, reliable supply of larvae and fries is the basis for stabilizing culture. Preparation of suitable feed for rearing fish fry is therefore important. In Japan, successful techniques now exist for mass production of the rotifer *Brachionus plicatilis*, the most efficient and essential food for the early larval stage of marine fish. Next, it is necessary to grow natural food and to formulate artificial preparations for post-larval stages of fish.

Diseases and epidemics are another concern of aquaculturists. Fungal, viral, and bacterial diseases have been diagnosed in several cultured

An aerial view of Suzakinomi Bay in the Kochi Prefecture. The rows of square rafts in the center of the bay support the net cages used for yellowtail culture. (Photo courtesy of Japan Information Center)

organisms, and have repeatedly resulted in mass mortality events. High priority must go to the prevention and control of diseases, and to the identification of causes of epidemics. Establishment of therapeutics on each disease is essential.

Environmental hazards caused by intensive use of aquatic areas also can result in declines in the productivity of culturing grounds. It is necessary to establish, for each culture area, the carrying capacity that will permit the normal life of organisms.

Finally, efforts must concentrate on cultivating new species to meet demands for seafood and fish. Selection and inbreeding promise rapid establishment and subsequent conservation of successful genetic lines. Induction of artificial gynogenesis (resulting embryo contains only maternal chromosomes) by irradiation of sperm and cold-shocking diploid (having the basic chromosome number doubled) eggs may result in the development of induced organisms with new and desirable biological characteristics. Parallel improvements in biological and technological methods will continue fostering aquacultural development.

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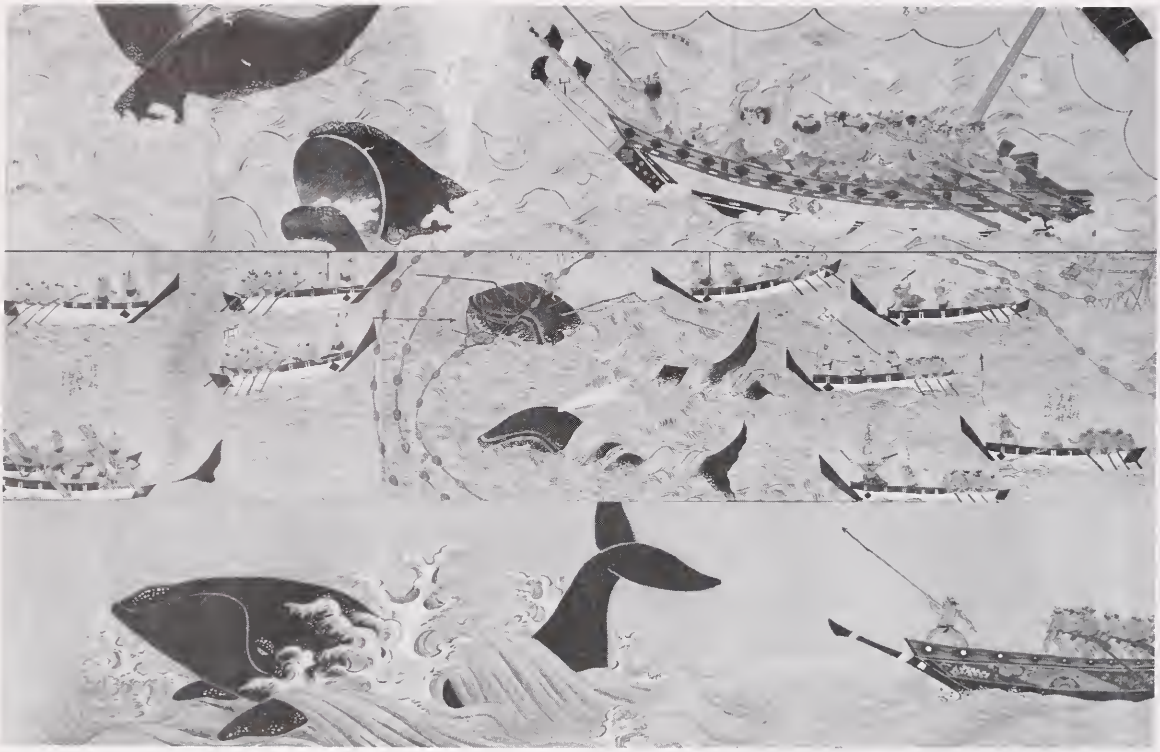
Whaling and Research

—Commercial whaling has come to its final season.

by Akito Kawamura

In June 1972, when the United Nations Conference on the Human Environment was held in Stockholm, Sweden, great whales suddenly became important symbols of the conservation movement. As a result, there was a vigorous new campaign to seek an end to whaling. Although the adopted resolution calling for a 10-year moratorium



on all commercial whaling was not fully accepted following the 24th Annual Meeting of the International Whaling Commission, since "there is no scientific justification for the blanket moratorium," more than a decade later, commercial whaling has come to its final season, after a long and complicated multi- and/or bi-national process.

The anti-whaling campaign made the Japanese public consider both the whales and whaling, increasing public awareness of these topics. Naturally, these problems were viewed differently by different generations. Older people generally valued the nutritional benefits of whale products, especially those who survived the decade immediately after World War II—when Japan experienced severe food shortages. This viewpoint stressed the need to supply whale products to the Japanese market during those days. A review of the supply-demand relationship for meat indicates that whale meat, as a share of the total meat supply, was about 10 percent during pre-war years, but became 41 to 47 percent during the years from 1947 to 1949. The traditional dietary use of whales is more than 400 years old in Japan, so there is a reluctance to cease whaling without good reasons. Many Japanese hope to retain their cultural traditions for as long as possible.

I am of the view that the end of whaling is regrettable not only from the viewpoints of food supply and tradition, but also for purely scientific reasons. Unlike other fish stocks it is impossible to obtain research materials on the great whales without the existence and cooperation of the whaling industry. Most of our present knowledge about whales was obtained by past and present whaling countries. Whales, and whaling itself, constitute a vast research field that has stimulated the interest of students of marine biology and many other related fields. Even so, the great whales are still poorly understood animals.

Scenes of right whaling in medieval Japan. Net whaling is clearly shown (middle panel). (From a scroll in the collection at The Historical Documents Division, National Institute of Japanese Literature, Tokyo)

On 28 October 1986, Japan's newspapers reported the factory ship, *Nisshin-maru No. 3*, was leaving Yokohama for her final expedition to the

Antarctic, signalling the end of commercial whaling in the Southern Ocean. It also meant the end of a component of great-whale research, through which we have learned so much.

Cultural Basis for Whaling

Historically, Japanese commercial whaling dates back some 400 years when Chubei Yorimoto Wada settled in Taiji village, a small town in today's Wakayama Prefecture. He and his whaling crew hunted mainly right whales, *Eubalaena glacialis*, using small boats and hand harpoons after 1606, although unorganized whaling activities date back to the years about 1570–1572. The famous whaling by Pyrenean Basques in the Bay of Biscay region for right whales corresponds to a similar time period.

Whale products from early whaling were abundant enough to be shared over wide geographical ranges. The ways of utilizing whale products were variable, but one worth mentioning is a use of whale oil as an insecticide in rice-growing fields. Especially after 1675, when nets were introduced and functioned well as whaling gear, and better delivery systems were introduced, the products of commercial whaling spread nationwide. Some dietary habits and many different traditional cultures that still exist in Japan are considered to have originated because of the relatively high production of whale products and their economic importance.

Kazuo Fukumoto, writing in the *Story of Japanese History in Whaling* provides some information on early whaling by *Masutomi Gumi*, a whaling crew in northern Kyushu:

Period of whaling	1726–1874
Number of whaling boats	more than 200
Number of whales caught	21,790 (about 146 whales per year)
Total number of persons	320,000
Total sales	3,320,000 *Ryo* (about 1290–1480 billion yen)

Throughout the changes in whaling methods, from hand harpoon, net whaling using small fire-arms such as the darting gun and bomb-lance, to the final modern Norwegian method in 1899, whales and whaling established their importance in Japanese fisheries.

Current Status

Unlike European whaling countries, Japanese whaling is traditional in the high utilization of whale meat in addition to whale oil, which is why the whaling in this country has long been a profitable business among many other fisheries, and was able to continue its activity under extremely small catch quotas during the past decades.

The Taiyo Gyogyo K. K., Nippon Suisan K. K., and K. K. Kyokuyo were the three major companies in factory ship whaling. Since the 1970s, however, the catch quota became too small to support three companies. On the advice of the Ministry of Agriculture, Forestry, and Fisheries, the whaling divisions of the three companies were finally merged, creating one consolidated

The factory ship, Nisshin-maru No. 3, *leaving Yokohama harbor on October 28, 1986. Upon her return, Japanese whaling in the Southern Ocean will have ceased. (Photo courtesy of the Kyodo Tsushin Press)*

company, the Nippon Kyodo Hogei K. K., in February 16, 1976. The new company bought a large amount of property, including three factory ships and 20 catcher boats, but some of them were sold or scrapped soon after. Finally, there remained one factory ship and 14 catcher boats. Of these, four boats are still in commission for whaling. Almost all whale products are distributed through the business network of their subsidiary companies and one addition, Nitto Hogei K. K.—one of the land-based whaling companies.

The structure of Japanese whaling activities as of the 1985/86 season, according to The Fisheries Agency, is as follows:

- One pelagic whaling company for southern minke whales (*Balaenoptera acutorostrata*), with 620 employees.
- Three land-based companies for sperm whales (*Physeter catodon*), and Bryde's whale (*Balaenoptera edeni*), with 5 land stations and 400 employees.
- Eight small management bodies (fishermen's associations or companies) for smaller cetaceans, such as minke whales, Baird's beaked whales (*Berardius bairdi*), killer whales (*Orcinus orca*), and several other species.
- Local dolphin and porpoise fisheries—variable by year and season.

During the past 19 seasons (Table 1), the total number of whales captured declined from 22,784 in 1966, to 4,473 in 1984, a reduction of about 80 percent, while the final proceeds declined from 28,960 to 13,920 million yen, a reduction of about 52 percent. Many reasons can be given to explain these figures, but contrasted with a need to support high market prices at the consumer's expense, the trend to reduced profits

Table 1. Catch of whales and production during the last 19 seasons (up to 1984).

	Catch						Production (Metric tons)				
Year	Fin	Sei/Bryde's	Sperm	Minke	Others	Total	Oil	Meat	Others	Total	Sales (Million Yen)
1966	2,280	13,829	5,583	365	727	22,784	88,545	180,215	11,080	279,840	28,960
1967	1,307	12,725	6,031	286	739	21,088	81,838	168,943	12,837	263,618	25,230
1968	1,395	11,915	6,861	836	579	21,586	81,213	156,766	16,850	254,829	23,670
1969	2,473	7,641	6,668	287	340	17,409	72,467	135,024	15,443	223,934	22,110
1970	2,416	7,287	6,548	330	306	16,887	72,604	139,230	15,836	227,670	27,190
1971	2,215	7,114	6,465	291	334	16,419	71,775	135,009	16,319	223,103	31,380
1972	1,760	6,706	5,573	3,354	197	17,590	61,196	121,926	11,350	194,472	27,710
1973	1,441	4,745	5,082	2,633	111	14,012	50,250	97,921	15,794	163,965	27,320
1974	945	4,571	4,579	4,085	97	14,277	42,794	89,592	13,141	145,527	32,730
1975	727	3,539	5,184	3,870	107	13,427	40,326	74,072	12,616	127,014	33,720
1976	118	1,977	4,132	3,377	28	9,632	24,518	43,594	9,187	77,299	21,590
1977	0	1,737	3,312	4,198	52	9,299	21,054	42,473	8,189	71,716	20,550
1978	0	516	2,561	2,800	47	5,924	12,827	24,327	5,008	42,162	12,410
1979	0	227	1,520	3,139	31	4,918	7,626	19,075	4,105	30,806	10,700
1980	0	307	1,192	3,658	34	5,191	7,166	20,538	4,540	32,244	12,610
1981	0	485	869	3,494	39	4,887	5,803	19,701	3,249	28,753	11,800
1982	0	482	439	3,901	145	4,967	4,686	21,016	2,910	27,713	13,170
1983	0	536	393	3,514	163	4,606	3,015	21,665	1,710	26,390	13,920
1984	0	481	400	3,394	198	4,473	2,713	21,064	1,477	25,254	13,920

Notes:
1. Catches under special permit are excluded.
2. Catches before 1979 for sei whale include Bryde's whale. Catches after 1979 are only Bryde's.
3. Year indicates the end of operations for the Antarctic season (1984 as 1983/84 season), but the beginning of the season for land-based operations.

from whale products must be a major factor. At present, there is no subsistence whaling in the literal meaning, although the whaling by smaller local management bodies could be categorized as subsistence whaling.

Following recent talks between Japan and the United States, all whaling activities except for dolphins and porpoises will end within the 1987/1988 period.

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Selected References

Allen, K. R. 1980. *Conservation and Management of Whales.* 108 pp. London: Butterworth & Co.

Department of Sea Fisheries, Fisheries Agency, 1986. *An Outline of Whaling.* 61 pp. Tokyo: Ministry of Agriculture, Forestry, and Fishery.

Fukumoto, K. 1978. *Story of Japanese History in Whaling.* 289 pp. Tokyo: Hosei University Press.

Kawamura, A. 1983. Large animals and plankton. *The Heredity,* 37:18–28.

Kawamura, A. 1986. Has the marine Antarctic ecosystem changed?—A tentative comparison of present and past macrozooplankton abundances. In *Proceedings of the Seventh Symposium on Polar Biology. Memoirs of National Institute of Polar Research, Special Issue,* No. 40, pp. 197–211. Tokyo: National Institute of Polar Research.

The Whales Research Institute

The Whales Research Institute, a private organization that functions as a center of cetacean research, was established on August 20, 1947, under the auspices of the whaling companies. The institute was almost completely independent from industrial affairs, and its activity was focused purely on the biological and ecological research of whales and marine mammals. All the research results have been published in the Scientific Reports of the Whales Research Institute, *which now includes No. 1 (1948) to No. 37 (1986), with 399 reports of more than 7,000 pages. The Whales Research Institute also functioned as a place to train marine mammalogists in Japan, since there were no university laboratories in this field.*

A great deal of the present knowledge about whales and whaling undoubtedly came from studying whales killed by whalers, especially from pelagic operations. With the worldwide reduction, and possible complete cessation, of whaling, this aspect of whale research will change greatly.

The Japan Marine Science and Technology Center

(JAMSTEC)

EDITOR'S NOTE: The functions and work of the Japan Marine Science and Technology Center (JAMSTEC) are described in the following seven articles, which present an overview and several project descriptions.

by Takashi Mayama

Japan—an island nation completely surrounded by the sea—is a country of scarce natural resources, limited land area, and frequent earthquakes. Despite Japan's small land area of approximately 370,000 square kilometers, its 200-mile Exclusive Economic Zone consists of 4.5 million square kilometers, ranking sixth in the world in terms of size. These territorial waters are a treasure house of mineral, biological, and energy resources;

Above foreground, the JAMSTEC facilities at Yokosuka on Tokyo Bay. The Nissan Motor Co. is in the background.

on the surface and below, they hold unlimited possibilities for ocean space utilization (see article page 66).

In May of 1971, the Japan Marine Science and Technology Center (JAMSTEC) was founded by a resolution of the 65th Parliament, through the cooperative efforts of government, academic, and private parties. It was founded for the purpose of promoting the marine science and technology of Japan in response to the social needs of the people. At its inception, it had a staff of 30 and a budget of Y6.5 million (US$3.8 million). In 1986, the staff had grown to 143, and the annual budget to Y7.4 billion (US$46 million).

The facility is located about 45 kilometers south of Tokyo, on Tokyo Bay (see map, page 5). It includes classrooms, shops, test and training facilities, a library, information services, and dockage facilities for its research vessels.

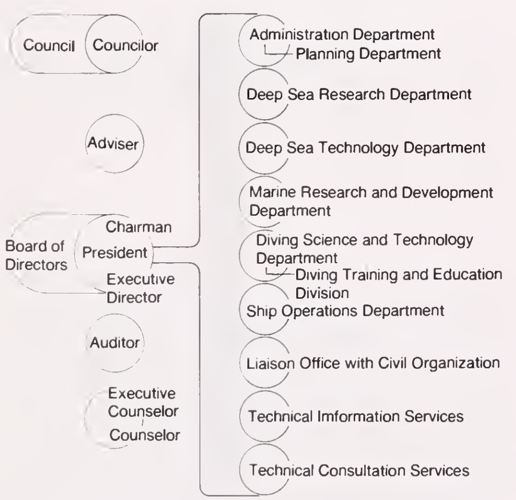
Functions of JAMSTEC

JAMSTEC has four principal functions. They are:

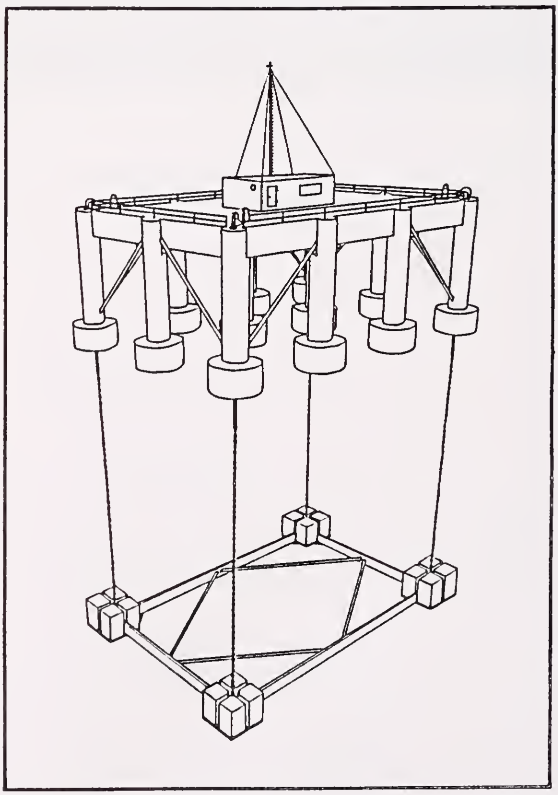
- Research and development. JAMSTEC is promoting R & D of advanced technologies in ocean floor surveying, data acquisition, ocean energy, and manned undersea work systems.
- Training. JAMSTEC is developing human resources by holding training courses on diving techniques and marine engineering seminars for researchers and technicians.
- Technical Information Services. As a specialized public organization for marine development, JAMSTEC is strengthening its function of actively gathering and disseminating information on marine science and technology.
- Operation and maintenance of facilities for public use. JAMSTEC establishes and maintains various types of large-scale testing facilities for public use. These facilities are also available to government, universities, and private enterprise. They include an undersea simulation and training facility, a high pressure test facility, and an underwater anechoic (free from echoes, designed for acoustic measurements) tank.

JAMSTEC's R&D is wide-ranging. It includes development and construction of manned and unmanned deep research submersibles, studies of optical fibers for deep sea cables, optical-electro-mechanical cables for remotely-operated vehicles, remote sensing by passive microwave, oceanic applications of laser, and new data acquisition buoys. One example of a present project is the design and construction of a prototype offshore floating structure—to be used as a stable ocean research laboratory.

This new JAMSTEC ocean platform is expected to become a valuable deep sea laboratory for long-term observation, a base for developing undersea work systems, and/or a test plant for marine energy utilization. The platform is semisubmersible, and includes 12 columns with footings (see drawing below). Perhaps the most unique component is the tension mooring system. Each of the four tension legs is a rubber-encased



JAMSTEC organization. JAMSTEC consists of one administrative department, four research departments, one ship operations department, and several other divisions.



The proposed JAMSTEC tension leg platform—a prototype offshore floating structure.

Sectional view of the rubber-chain combination to be used for mooring the prototype platform.

chain—a combination that will absorb shock loads and protect the mooring line from local abrasion.

As a maritime nation, it is important for Japan to develop these systems to the point where they are operational. This requires cooperation between government agencies, academic institutions, and the private sector—with *JAMSTEC* acting as the catalyst.

Sponsors' Group

Since the establishment of JAMSTEC in 1971, the Japan Federation of Economic Organizations (*Keidanren*—see list of organizations, page 8) has served as a channel between JAMSTEC on the one hand, and private enterprises and business organizations on the other, for the purpose of identifying mutual interests and coordinating financial matters.

After the conclusion of the first phase of the funding plan in 1975, additional private-sector cooperation was sought. As a result of consultations with STA, *Keidanren*, and the businesses concerned, a decision was reached to initiate a sponsors' group (see page 8).

The sponsors' group was inaugurated in 1976. Since then, there has been a heightened awareness of Japan's marine development. Businesses related to marine development, and organizations interested in marine development, have been invited to join the group to help pinpoint specific needs, participate in joint studies, and to cooperate in financial matters.

As of the end of fiscal 1984, the group's membership consisted of about 160 business organizations and private companies—primarily involved in such fields as shipbuilding, electricity, steel, and machinery. With the support of this sponsors' group, JAMSTEC is promoting R&D targeted at the needs of the businesses responsible for the future of Japan's marine industry.

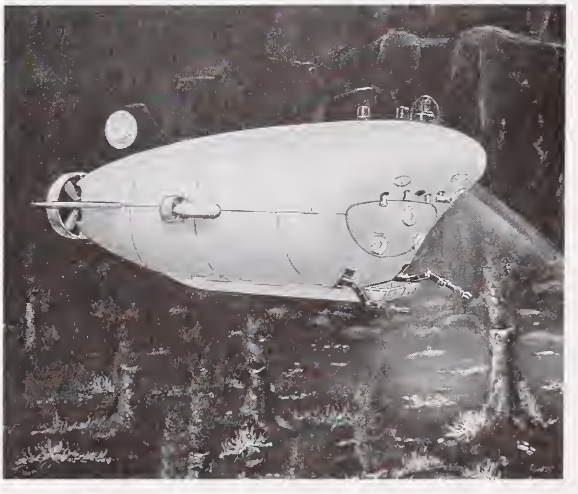
Takashi Mayama is the Executive Director for Planning at JAMSTEC.

Deep Submersible Project (6,500 m)

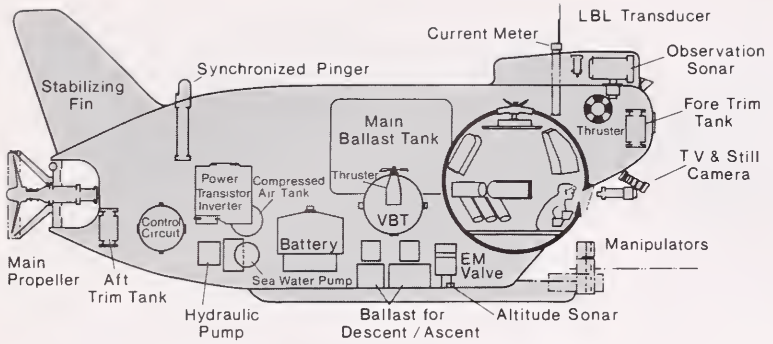
by Shinichi Takagawa

In the late 1960s, the Japanese government decided to develop a manned research submersible capable of diving depths to 6,000 meters. However, at that time, Japan had no experience in the development or the operation of deep submersibles. Therefore, it was decided in 1977 to develop a medium-depth submersible to obtain experience with development and operation. As a result, the 2,000-meter deep manned research submersible *Shinkai 2,000* was launched by JAMSTEC in 1981. Through the development and operation of this intermediate submersible, JAMSTEC obtained the confidence to develop and operate a new 6,000-meter-class deep manned research submersible. The budget for the development of the submersible has been approved. It is now in the preliminary design stages at JAMSTEC, with a launch date projected for 1989.

Two of the principal missions for the new submersible will be in research on hydrothermal deposits, and on trench-slope research important to earthquake prediction. With a 6,000-meter depth capability, Japan will be able to conduct



Artist's rendering of the JAMSTEC 6,500 meter research submersible, scheduled for completion in 1989.



Planned layout of Japan's new 6,500-meter research submersible.

research in up to 98 percent of the World Ocean, and 94 percent of the Exclusive Economic Zone (EEZ) ocean surrounding Japan.

Principal Requirements

Generally speaking, the submersible should be small and light so as to make launch and recovery work easy. The mobility should be good so as to make the research mission effective. Lastly, because the major mission will be research of the deep-ocean floor, traveling time from the surface to the bottom and from the bottom to the surface should be as short as possible.

Initially, JAMSTEC considered 6,000 meters for the maximum depth capability because such capability could cover 98 percent of the World Ocean. However, Japan and its surrounding ocean have a special condition. The islands of Japan are surrounded by several deep trenches—places where large-scale earthquakes occur frequently. Geophysicists consider it to be most important to survey not only the top of the trenches (about 6,000 meters deep), but the bending part of the ocean-floor plates just below the top of the trenches. Accordingly, the maximum depth capability has been increased to 6,500 meters.

Diving to this depth takes a very long time (nearly 5 hours one way) if the vertical speed is the same as that of the *Shinkai 2,000*. After hydrodynamical calculations and wind-tunnel experiments, it was decided to slim the body of the submersible for more rapid vertical movement. With this change, it is expected that the one-way traveling time to a depth of 6,500 meters will be about 2.5 hours.

The normal diving duration is planned as 9 hours (3 hours for research, 5 hours for descent and ascent, and 1 hour for launch and recovery). The maximum life support duration was decided to be 129 hours for three crew members. This adds 5 days beyond the normal diving duration.

The other requirement on the shape was to be able to look upward through one of the viewports. Because of her long eaves, this was not possible from the *Shinkai 2,000*. After the study on weight distribution, a shortening of the eaves was realized by transferring heavy subsystems to the afterbody. The eaves were also inclined—a shape that not only allows the operators to look upward, but also reduces the hydrodynamic drag for vertical movement.

Another request from the operators was to eliminate the auxiliary thrusters extruded from the body, and instead, to adopt tunnel thrusters for vertical and horizontal use from the viewpoint of avoiding entanglement. Thus, the propulsion system became very similar to France's three-man deep-diving submersible *Nautile*.

The Pressure Hull

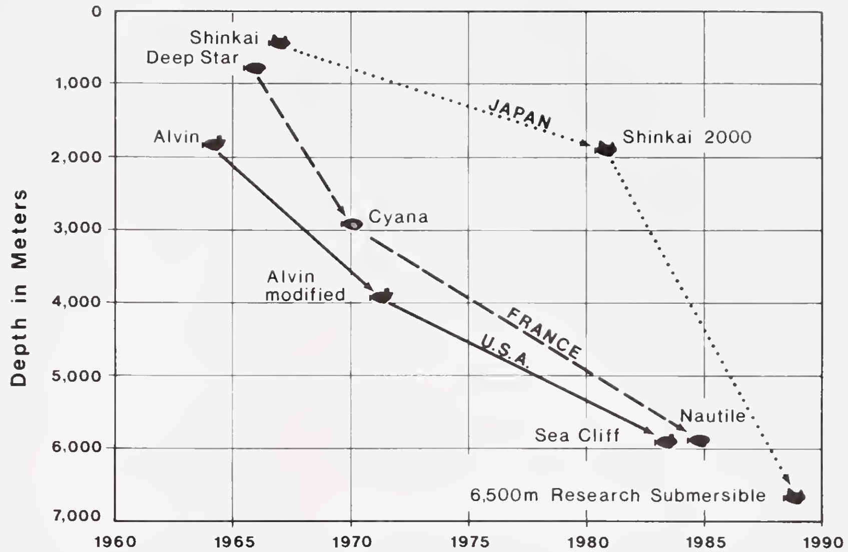
The weight of the pressure hull occupies a large amount of the total weight of the submersible. To reduce the former reduces the latter significantly. During the construction of the *Shinkai 2,000* (*Shinkai* means deep sea), Japan had no facility to produce a titanium alloy pressure hull. Since then, the facilities and technology have become available, and a titanium alloy (Ti-6A1-4V ELI) pressure hull was adopted. To further reduce the total weight of the submersible, a reduction in hull diameter was considered. Many human-engineering experiments were carried out to examine the feasibility of a pressure hull with an internal diameter of 2 meters. The test results showed that such a size was feasible, and a 2-meter internal diameter titanium alloy pressure hull was decided upon.

As the size of the pressure hull was reduced, a rearrangement and redesign of equipment inside the hull also was necessary. The experiences of the operators of the *Shinkai 2,000* were combined with human-engineering and feasibility studies. A major redesign of the interior resulted.

Included in the design were three 120-millimeter internal-diameter viewports, one at the front-center, inclined 15 degrees below the horizontal plane; and two lateral—one each at 50 degrees to the left and right of the sphere, inclined 25 degrees from the horizontal.

Further Refinements

The welding technology developed by Japan for the titanium pressure hull also was applied to the exostructure. The frames of the new submersible



Status and development of deep research submersibles in the U.S.A., France, and Japan.

are pure titanium or titanium alloy. Welding the frames, rather than bolting them, contributes to overall weight reduction.

Shinkai 2,000 uses silver-zinc batteries for her energy source with satisfactory results. The new submersible also will use silver-zinc batteries with increased capacity and life. The motors of the *Shinkai 2,000* are induction motors, and direct current from the batteries is inverted to alternating current by a power transistor inverter in order to control and drive the motors. At the time of the construction of *Shinkai 2,000* there was no technology to immerse power transistors into oil to compensate for the ambient pressure. Since then, Japan has developed such technology, and JAMSTEC will use an oil-immersed pressure-compensated power transistor inverter. Only the control circuit for the inverter will be contained in a pressure vessel.

One weak point in a submersible is that its operators cannot look at objects some distance away from it because of the light absorption by seawater. The underwater acoustic signals usually used by submersibles can reach long distances. However, most sonar information usually indicates only that there is a target but shows little about the shape. Under cooperation with a Japanese company, JAMSTEC is now developing an observation sonar system that can show the shape of the target just like a TV image. The principle is the same as acoustic tomography. The maximum range will be 200 meters.

The operators of the *Shinkai 2,000* also requested a change in the new sub's manipulator arrangement. While the *Shinkai 2,000* has a single manipulator, its operators requested that the new submersible be fitted with two manipulators with easier handling. This was taken to heart, and the new submersible will have two manipulators, one of which is a 7 degree-of-freedom master-slave type with a force feed-back system, and the other a 5 degree-of-freedom joystick-control type.

The buoyancy material for the new sub is already on hand. Buoyancy material is an important part of any submersible system—it should withstand the pressure yet be light in weight. JAMSTEC has developed a buoyancy material whose collapse pressure is more than 1,200 kilograms per square centimeter and whose density is 0.54 grams per cubic centimeter by adopting a binary glass microballoon mixture method. JAMSTEC will use this buoyancy material for the new submersible.

The depth capabilities of the new submarine, however, did require changes in the acoustic location method. The location of *Shinkai 2,000* is detected by using underwater acoustic transponders. But, the deeper depths of the new submersible make the distances longer. These distances make the signal level small and receiving misses often occur. To avoid such misses, the new submersible will have synchronized pingers similar to the Woods Hole Oceanographic Institution's (WHOI's) *Alvin*, which can dive to 4,000 meters. The U.S. Navy's *Sea Cliff* submersible has the capacity to dive to 6,000 meters.

Support Vessel

To operate the new Japanese submersible effectively requires a proper support vessel. *Natsushima*, the support vessel for *Shinkai 2,000*, is a quiet vessel, in order to avoid disturbances by ship-emitted noise to the underwater acoustic communication/location system. However, the support vessel for the new submersible will be quieter than *Natsushima* by more than 10 decibels, required by the greater travel distance for the communications. While the diving area of the *Shinkai 2,000* system is limited to the area close to shore because of its depth capability, the diving area of the new system will be far from shore, and the operational sea state conditions are expected to be more severe than *Natsushima* was designed for. JAMSTEC is now planning to construct a support vessel whose noise emission is fairly small, and which can operate in heavier sea conditions.

Cooperative Program Needed

The construction of the new submersible will be completed by 1989. When completed, there will be three countries in the world—the United States, France, and Japan—with deep manned submersibles. Japan wishes to establish an international cooperative program for deep sea research, and also wishes to establish a mutual rescue program for deep manned submersibles with countries that have submersibles of the same depth capabilities.

Shinichi Takagawa is a naval architect, and Assistant Senior Research Engineer in the Deep Sea Technology Department, JAMSTEC.

Deep Sea Research Around the Japanese Islands

by Hiroshi Hotta

The *Shinkai 2,000* has been operated by JAMSTEC since 1983 for research around the Japanese Islands. This is the first Japanese research submersible capable of diving to a depth of 2,000 meters. It has a scientist/crew complement of three. The dive program is funded by the Japanese government on the basis of about 70 dives per year in the waters around Japan.

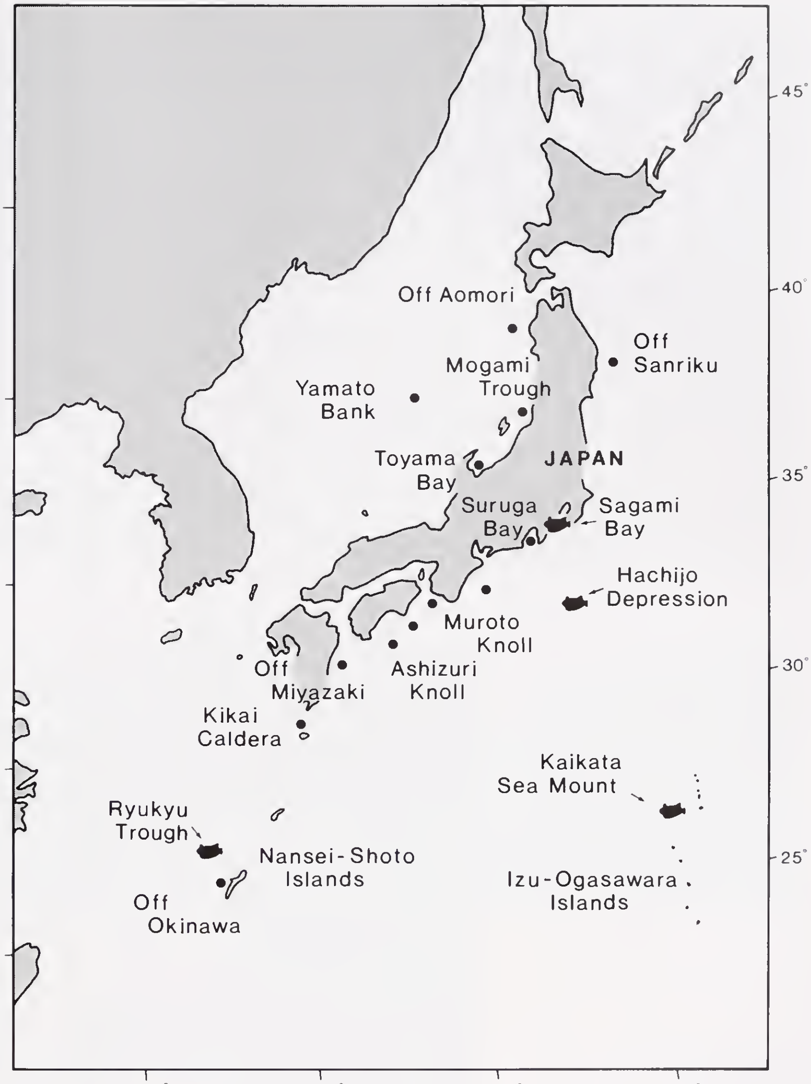
Recently, the utilization of the sub was reviewed by a steering committee after three years of operations, taking into account the results and advances in deep sea research throughout the world. The new guidelines adopted by the committee stress joint research programs by several cooperating institutions and/or universities. This differs from the initial operations, when the sub was used for projects that were individually proposed by governmental institutions and universities. One of the suggested new major objectives is geoscientific and tectonic studies in Suruga and Sagami bays at central Honshu in the Pacific, and in the Japan Sea in relation to earthquake prediction research. Another recommended study is the investigation of the rift systems in the Izu-Ogasawara (Bonin) and the Nansei-Shoto (Ryukyu) Islands, with the object of locating hydrothermal areas with the potential of exploitable ore deposits.

The first joint diving program by *Shinkai 2,000* was carried out in May of 1986 in Sagami Bay to study deep sea biological colonies from the geoscientific, geochemical, biological, and microbiological points of view. Colonies dominated by giant clams, *Calyptogena soyoae*, were unexpectedly discovered in the bathyal zone of Sagami Bay during dives in 1984 and 1985 at the foot of a slope extending from the Izu Peninsula. The deep biological colonies along suspected cool water seepage sites were reported by Erwin Suess, a biologist at Oregon State University, and others, in the 1985 *Bulletin of the Biological Society of Washington*. Research on these types of sites continues in waters off Oregon, the Florida Peninsula, and the Japan Trench.

Prior to the dive, a series of pre-site surveys were conducted using the JAMSTEC/Deep Tow, which consists of a 70-kilohertz side-looking sonar, a 4.8-kilohertz subbottom profiler, and color TV and 35-millimeter still cameras. The surveys disclosed that a large number of the giant clam colonies extended over roughly 7 kilometers from north to south along the steep slope at depths between 900 and 1,200 meters. The colonies were dotted around the volcanic outcrops of angular boulders with abundant dead clam shells scattered in and around the colonies. It was observed that living clam colonies tended to be located in the north, with more dead colonies in the south.

In a total of nine dives made at the site, it was verified that the colonies consist of organisms such as clams, tube worms, crabs, small gastropods, and eel-like fishes; and are occasionally fringed with white mud—some type of bacterial mat. This assemblage is similar to that found in the waters off Oregon and Florida. The biggest colony at the site was estimated as at least 30 meters by 200 meters.

A further series of dives was carried out in the Ryukyu Trough soon after the Sagami Bay expedition. The Ryukyu Trough is one of the most interesting areas around the Japanese islands, and studies on formation and back-arc volcanism have been described by M. Kimura, a geologist at the University of the Ryukyu (see references). Geological and geophysical data on the area have been accumulated by various research institutions in several countries. With this background, four preliminary dives were made. Very fresh volcanic rocks were observed over the knolls in the trough. These preliminary surveys strongly suggested the need for follow-up dives in the trough. In the summer of 1986, 11 additional dives were made. During the second dive, a cluster of mounds was discovered. They are about 10 meters across, 2 to 5 meters in height, are generally covered by dark-colored material, but have yellow to bright orange-colored deposits over the top and ridges. Closer observation revealed apparent plumes of water and temperatures of 42 degrees Celsius inside a small chimney on the mound. This was the first discovery of a hydrothermal vent in the back-arc basin around the Japanese Islands. No biological communities were observed around the mounds. Comprehensive studies by the submersible will be continued in coming years.



Dive sites around the Japanese Islands. The submarine symbol indicates sites referred to in the text; dots indicate other sites.

Another intriguing dive site for the study of back-arc volcanism is over the Izu-Ogasawara (Bonin) Ridges. Eight dives over the ridge were made in the fall of 1986. Two dives of this series were allocated to American scientists, Alexander Malahoff, a geologist and professor at the University of Hawaii, and Marjorie Reaka, a biologist and associate professor at the University of Maryland. Their dives were the first in an international cooperative program for the *Shinkai 2,000*—arranged by the Japanese Science and Technology Agency and the U.S. National Oceanographic and Atmospheric Administration (NOAA) under the U.S.-Japan Conference on Development and Utilization of Natural Resources. The dives were successful, and the results seem to clear the path for future long-term international cooperative research.

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References

Hamada, Y., S. Takagawa, T. Ikeda, M. Sunaga, M. Endoh, and K. Yokota. 1982. On the development of the Japanese 2,000-m deep submergence research vehicle Shinkai 2000 system. In *Proceedings of OTC'82 Conference*, pp. 251–230.

Kimura, M. 1985. Formation of the Okinawa Trough. In *Formation of Active Ocean Margins*, ed. N. Nasu, pp. 567–591. Tokyo: Terra Scientific Publishing Company.

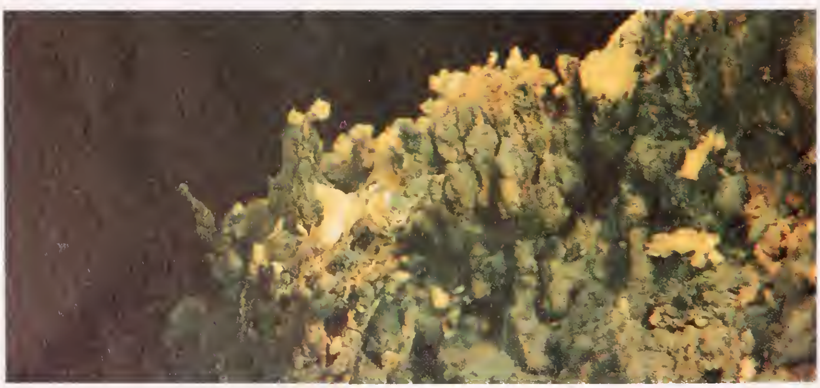
Suess, E., B. Carson, S. D. Ritger, J. C. Moore, L. D. Kulm, and G. R. Cochrane. 1985. Biological communities at a vent site along the subduction zone off Oregon. *Biological Society of Washington Bulletin* 6: 475–484.

The Research Group for Active Faults. 1980. *Active Faults in Japan—Sheet Maps and Inventories*, 363 pp. Tokyo: University of Tokyo Press.

Uyeda, S., M. Kimura, T. Tanaka, I. Kaneoka, Y. Kato, and I. Kushiro. 1985. Spreading Center of the Okinawa Trough. *Technical Reports of Japan Marine Science and Technology Center—Deep Sea Research Special Issue*, pp. 123–142. Tokosuka, Japan: Japan Marine Science and Technology Center.

Tube worms discovered for the first time in the spring of 1986 in the Sagami Bay dives. This genus has not been previously reported in the Western Pacific. These tube worms are approximately 1 centimeter in diameter and 60 to 70 centimeters in length.

An elongated cluster of giant clams, mostly all alive. Their average size is estimated at 9 to 12 centimeters in length. The tip of the manipulator containing a water sampler tube is seen in the center foreground.



A close-up of a hydrothermal mound discovered in 1986 in the Okinawa Trough, the first discovery of hydrothermal venting around the Japanese Islands.

Kaiyo, a Unique Research Vessel

by Yoshitaka Odani

Kaiyo, "the ocean" in English, is the largest Small Waterplane Area Twin Hull (SWATH) vessel in the world (61.5 meters). The vessel, featuring a unique ship design and advanced facilities, was placed into service in June 1985.

Her superior stability and seaworthiness in waves (where a monohull ship will roll 30 degrees, *Kaiyo* will roll 5 degrees) are achieved by the combination of twin small waterplane struts, and submerged lower hull forms with fin stabilizers. Her wide beam (28 meters) affords greater deck space than a conventional monohull ship with the same displacement.

In addition to these general advantages of a SWATH-type vessel, elaborate design of the *Kaiyo* navigation system, position keeping, underwater noise control, and associated research facilities contribute to support the multi-disciplinary research and development conducted by the Japan Marine Science and Technology Center (JAMSTEC) on and under the sea.

Research Activities Supported by *Kaiyo*

In her first 10 months of service from June 1985 to March 1986, *Kaiyo* maintained a heavy schedule to support various research programs of JAMSTEC, and also to acclimate her crew to her motion behavior, which is not all the same as a conventional monohull ship (the SWATH vessel has a longer roll period than does a monohull ship). When tilted, a monohull ship can revert to its original position quickly, whereas the SWATH reverts slowly (see diagram). Therefore, persons experienced in operating monohull ships may find the motions of SWATH quite strange at the beginning.

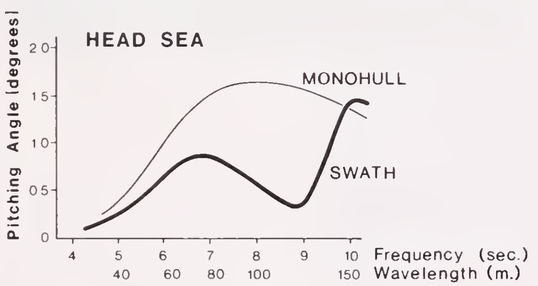
The initial research conducted aboard *Kaiyo* fell broadly into four categories, which are elaborated upon somewhat in the following.

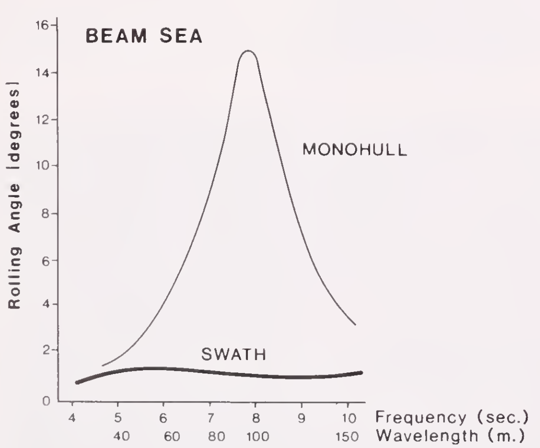
Experiments in Deep Diving. Mooring *Kaiyo* by four anchors, and using a deep diving system housed aboard *Kaiyo*, phased experimental dives up to 100 meters were achieved as a preliminary step to the 300-meter dives scheduled for 1988. For the 100-meter dive, six test divers lived 11 days in the hyperbaric (high-pressure) environment created in a deck decompression chamber (DDC) and took a submersible decompression chamber (SDC) to and from the work site at the sea bottom 100 meters deep. Underwater work experiments there were carried out by the test divers locked out (exiting from and returning to the submerged chamber) from October 29 to November 2, 1986. In December 1986, unmanned preliminary experiments to both 200 meters and 300 meters were conducted while *Kaiyo* maintained her position using a dynamic positioning system (DPS).

Experiments with a *New Oceanographic Observation System.* Aiming at efficient ocean survey, JAMSTEC has been developing an advanced measuring system for oceanographic observation since 1977. In this connection, *Kaiyo* has supported a series of sea trials to assess the utility of a high-speed towed sensing system designed to make real-time vertical profile measurements. Towed by *Kaiyo* at a speed of four to six knots, a "fish" with sensors swims up and down vertically along a towing cable equipped with two depressors—one near the sea surface and the other at a depth of 200 meters. By putting these vertical profiles together in parallel at certain intervals, underwater parameters such as salinity, temperature, and depth are observed three-dimensionally. This measuring system was applied successfully on a cruise to the Kuroshio Current area in the East China Sea conducted from late September through early October 1986 under the Japan-China joint program commenced in 1986. Taking oceanographers from both countries onboard, *Kaiyo* experienced her first foreign voyage and visited maritime communities in Quingdao, China (see also "Oceanography in China," *Oceanus*, Vol. 26, No. 4).

The Deep Towed System. JAMSTEC has built and is operating a deep-towed survey system consisting of a towed open-frame vehicle and control unit, which is equipped with deep-sea cameras and sonars. *Kaiyo's* first use of the system was in September and October 1985 off northeast Japan. The performance of *Kaiyo* in this operation compared well with the more conventional research vessel *Natsushima* of JAMSTEC. These cruises also featured the first practical use of *Kaiyo's* multi-narrow beam echo sounder, providing sea bottom topography charts as the ship cruised.

Tests of a New Deep ROV DOLPHIN-3K. Manufacturing of the deep ROV (remotely operated vehicle) system designed by JAMSTEC is scheduled for completion in March 1987. With a depth capability to 3,300 meters, the system will be used for sea bottom survey and also in part to presurvey dive areas for the research submersible *Shinkai 2,000*. *Kaiyo* has served in support of sea tests of the ROV system, and will support a training program for the ROV system operations team.





Comparison of motion characteristics for a conventional monohull vessel and a SWATH vessel.

Advantages of *Kaiyo* for Ocean Research

As various maritime and research institutions throughout the world study the advantages and disadvantages of SWATH vessels, we at JAMSTEC have experienced rather favorable results. The key findings are as follows.

Comfort. Working time of researchers has been extended, and a reduced tendency for seasickness is evident. Either on-station or underway, *Kaiyo* has a good reputation for great stability, and a spacious deck area which contributes to safe, efficient, and precise work.

Precise Position-Keeping. When functioning as an offshore base for manned and unmanned underwater projects, *Kaiyo* can hold her position at a fixed point for a prolonged period by multi-anchoring, or with a dynamic positioning system (DPS) controlled manually or in a fully automatic mode. In less than 100 meters, unassisted four-point moorings maintain her position. For greater depths, up to 6,000 meters, a Japanese-made DPS processes the input navigation signals and controls the required thrust for the main propellers and side thrusters. In underway ocean surveys, DPS is of great use in navigating along the preset survey routes.

Low Underwater Noise Level. To minimize the underwater noise emission from the vessel herself, *Kaiyo* applies an electrical propulsion system. Further, vibration and noise-generating sources are arranged far above the sea-surface level

The Ship Research Institute

Japan's Ship Research Institute (under the Ministry of Transport) is to shipbuilding what JAMSTEC is to marine science—a mating of industry and government intended to foster the interchange of ideas—in this case, ideas in shipbuilding. Primarily occupied with the design of large petroleum-related tankers, the institute also works closely with Japan's two biggest shipbuilders, Mitsubishi and Mitsui, in the production of research vessels such as the SWATH ships. The institute's scope is comprehensive, with headquarters and 10 research divisions located in the Mitaka District, and branches in Osaka and Ibaragi prefectures.

Researchers in the area of Ship Propulsion are engaged in the hydromechanics of ship resistance and propulsion with the goal of developing the optimal ship hull form and propeller design. Present research centers on maximizing resistance reduction through the numerical study of the flow field around the hull, and boundary layer control.

The Ship Dynamics Division works on problems in hydrodynamics related to ship motion in waves, and wave load. Their goals include the analysis and quantitative prediction of wave load, as well as the development of the Control Configurated Vehicle—a highly maneuverable ship.

Studies on the development of safer and more economical ships, and estimates of their strengths come under the division of Structure Mechanics.

The Power and Energy Engineering Division is designed for the purpose of perfecting marine engine and energy technology, through the development of innovations—such as engines capable of using alternate energy sources, highly efficient ceramic engines, and the development of highly reliable engines by utilizing a laser measurement system.

The Material and Processing Division was created to evaluate the properties of structural materials and engines. Recent projects include the inspection of microscopic damage of materials by using ultrasonic waves and magnetism.

The area of Ship Equipment is currently engaged in the creation of advanced techniques for the prevention and control of marine pollution as well as the construction of life-saving systems and equipment.

The System Engineering Division is working toward the development of an automatic marine traffic and navigation system and a new shipbuilding system (Computer Integrated Manufacturing System).

Researchers in the Nuclear Technology Division are engaged in the basic and theoretical study of nuclear powered ships and also in the study of radioactive waste and spent fuel transport.

The division of Ocean Engineering is concerned primarily with the utilization of the ocean area, and advancing the development of ocean resources—studying the development of oil drilling rigs and the maneuverability, seaworthiness and stability of floating stations. Present research includes estimation of the safety of towing or installing offshore structures in the sea.

The Arctic Vessel and Low Temperature Engineering Division is occupied with the development of arctic tankers, the development of ice-transiting commercial ships and liquid natural gas carriers, and studies on the properties and strength of materials used at very low temperatures.

The Osaka Branch of the Ship Research Institute is located in Osaka City—the center of ship and ship equipment building in Japan. The Osaka Branch carries out research for the purpose of understanding and analysing shipbuilding materials such as structure material for small ships, as well as tests and studies on ship equipment. Researchers currently are working toward the development of sensor technology for detection of electrostatic charge in cargo tanks, and investigating techniques for minimizing the residues of ships carrying chemical products.

The Tokai Branch utilizes the facility of the Japan Atomic Energy Research Institute in Tokai Mura, Ibaragi Prefecture, and is engaged in the maintenance of nuclear fuel and shield structures for ship engine reactors. Present research priorities include the development of a code system for the estimation of the safety of radiation shields, and studies on the estimation of radioactivity of returnable waste in the spent-fuel transport flasks.

so that underwater acoustic communication and data acquisition are not hindered.

Easy Handling of Underwater Equipment. In the middle of the deck, where ship motion is the least, a center well (central deck opening) and A-frame crane are provided so that equipment can be lowered and raised safely and easily.

Advanced Auxiliary Facilities. Two of the major research facilities built-in to *Kaiyo* include a deep diving system and a multi-narrow beam echo sounder known as Sea Beam. The deep diving system allows experimental saturation diving up to 300 meters, or observation diving to 500 meters. It consists of a deck decompression chamber (DDC),

The deep ROV (remotely operated vehicle), Dolphin-3K, *in garage ashore.*

two submersible decompression chambers (SDCs) and a main control console (MCC). The DDC enables six test divers to reside for an extended period of time under a hyperbaric environment equivalent to the depth of the underwater work site. The SDC takes three divers at one time to and from the work site through the center well. The pressure level inside the SDC is kept the same as the work site for saturation diving, and is kept at atmospheric pressure for observation diving. The MCC monitors and controls environmental conditions inside the DDC and SDC, such as pressure level, mixed breathing gas composition, humidity, and temperature. The behavior and physiological condition of the test divers also are monitored and supported through television and communication systems.

The Multi-Narrow Beam Echo Sounder is a precision bathymetric survey system capable of producing contour plots of the sea bottom up to a depth of 11,000 meters in real-time. The transmitting array consists of projectors mounted in a line array at the bottom of the lower hull of *Kaiyo* and the receiving array consists of hydrophones arranged perpendicular to the transmitter. By processing the depth information from the multi-beam signals, an accurate contour chart is drawn with the swath width surveyed along *Kaiyo's* track corresponding to approximately 80 percent of the water depth.

Engineering Challenges

Because of the peculiar structure of the ship, special care was exercised in the design to ensure structural strength. The results have been satisfactory. In rough seas, with a sea state value of 7 to 8, the actual ship showed approximately the same stress resistance value as that expected from calculations performed during the planning stage. Even when subjected to flexing, the ship developed no problems in regard to structural strength.

Yoshitaka Odani is Director, Ship Operations Department, Japan Marine Science and Technology Center (JAMSTEC), Yokosuka, and a member of the Marine Technology Society.

Selected References

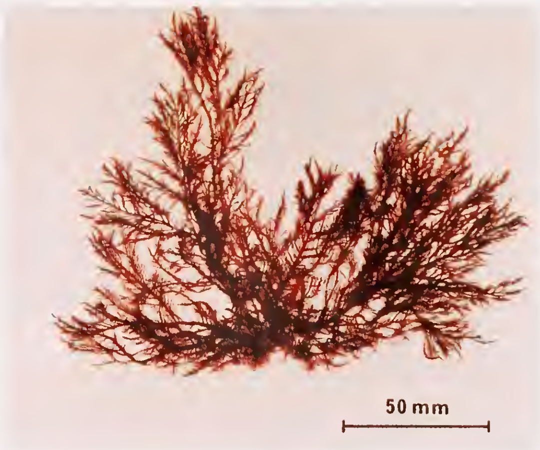
Gore, G. L. 1985. SWATH ship. *Naval Engineering Journal* 97: 83–112.

Lee, C. M. 1986. A general overview of SWATH hydrodynamics. *Naval Research Review* 38: 16–26.

Vine, A. C. 1982. The case for semisubmerged research ships. *Oceanus* 25: 15–17.

Using Deep Seawater For Biological Production

by Takayoshi Toyota, and Toshimitsu Nakashima



*Agar-agar (*Gelidium amansii*), a type of edible red seaweed.*

Since earliest time man has used the oceans as a source of food protein. Japan is among the world's greatest consumers of fishery products, attaining a marine catch of more than 10 million tons annually during the 1970s. However, overfishing has caused a drop in the amount of these resources, and overintensive utilization of marine areas has resulted in the declining quality of fishing grounds. To offset these problems, Japan has encouraged the development and augmentation of aquaculture technologies, including ways to increase resources in coastal areas, and the restoration and improvement of fishing grounds.

Phytoplankton are basic to the production of fish and shellfish in the oceans. In the upper layers of tropical/subtropical seas and temperate seas during summer, a lack of necessary nutrients depresses productivity. It is known, however, that upwelling marine areas, where a supply of deep seawater rich in nutrients to the production layer is sustained, are associated with active growth of phytoplankton, which represent the starting point of the food chain, forming beneficial fishing grounds. According to a report published in *Science* by John H. Ryther, an oceanographer at the Harbor Branch Institution, Fort Pierce, Florida, upwelling regions occupying 0.1 percent of the world's total ocean surface produce some 50 percent of the total fish catch.

The possibility of artificially creating deep seawater upwellings, rich in biological production potential, to replicate the high productivity of natural upwelling regions has intrigued fisheries scientists, oceanographers, and fishery operators alike for a long time.

At the 1972 Offshore Technology Conference, Oswald A. Roels, an oceanographer at Columbia University, and his associates presented a study conducted at the artificial upwelling laboratory in the Virgin Islands, demonstrating the beneficial effects of deep seawater to marine productivity. In that study, deep seawater was pumped up from a depth of 870 meters through a pipeline to a land-based tank, where the water was used to culture diatoms, which in turn provided food for rearing oysters and scallops.

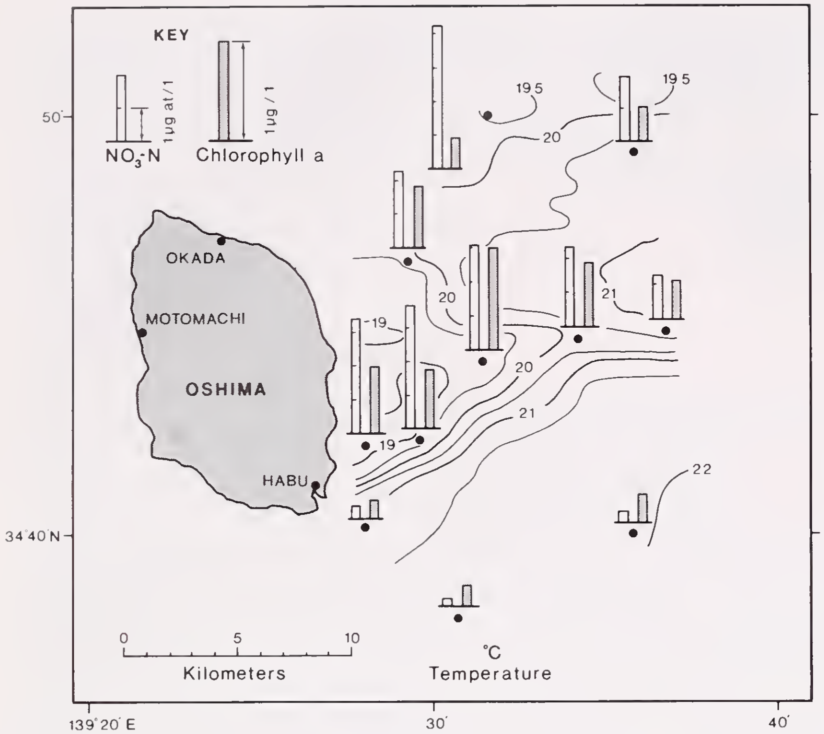
Deep Seawater Utilization Studies

Against the backdrop of these developments, the authors have been conducting research since 1976 on the utilization of deep seawater for biological production, in particular the properties of deep seawater, its effects on biological productivity, and the concept design of a deep seawater utilization technology.

We have investigated the physical, chemical, and biological properties of deep seawater lying below the biologically productive layers of seas in the vicinity of Japan. The deep seawater characteristically is rich in nutrient nitrates, phosphates, and silicates; low in temperature, with relatively stable temperature variations; and low in dissolved organic substances, suspended solids, and man-made pollutants. It also is relatively free from pathological organisms, parasites, and other harmful organisms.

Using batch and continuous culture techniques, we have assessed the benefits and influence of deep seawater with regard to the reproduction and the composition of species of cultured phytoplankton and natural phytoplankton. We found that:

- In the presence of deep seawater, phytoplankton multiply rapidly, with diatoms predominating in this process.
- Some phytoplankton can suffer from a growth lag, which can be shortened or eliminated altogether through the addition of an organic chelator (produces chemical binding of a metal to increase availability for growth), or by mixing the deep seawater with surface water.
- In deep seawater, phytoplankton tend to increase in size.



Horizontal distribution in the surface layer (at a depth of 2 meters) of temperature, nitrate nitrogen, and chlorophyll-a in regions off Oshima Island (May 25, 1982). The dark circles indicate water sampling locations.

- In continuous culture experiments, most of the nitrate nitrogen and phosphate phosphorus present in the deep seawater were converted to phytoplankton. Also, the faster nutrients were supplied in deep water, the greater was the increase in the phytoplankton's size and yield.

Survey of Natural Upwelling Regions

It would seem that there should be a considerable parallel between phenomena observed in natural upwelling regions and those induced by artificial upwelling of deep seawater. Therefore, we used data from local upwelling regions formed in the vicinity of Oshima Island and Miyakejima Island to study the effects of deep seawater on the production of beneficial marine products.

Since Oshima and Miyakejima islands are washed by the strong Kuroshio Current, swirling upwelling regions often occur in the rear (to the East) of the islands facing the Kuroshio Current. The chart on this page shows the water surface distributions of temperature, nitrate nitrogen, and chlorophyll in the sea region lying downstream of Oshima Island. The upwelling region shows a distribution of high concentrations of nutrients and chlorophyll, an indicator of the amount of phytoplankton present, compared with surrounding regions. This region also is rich in seaweed, forming an excellent environment for the growth of juvenile fishes and a fishing ground.

Similar characteristics also were observed in the region surrounding Miyakejima Island. The shallow sea bottom lying in the upwelling region produced a large volume of stationary organisms such as beneficial seaweed and shellfish.

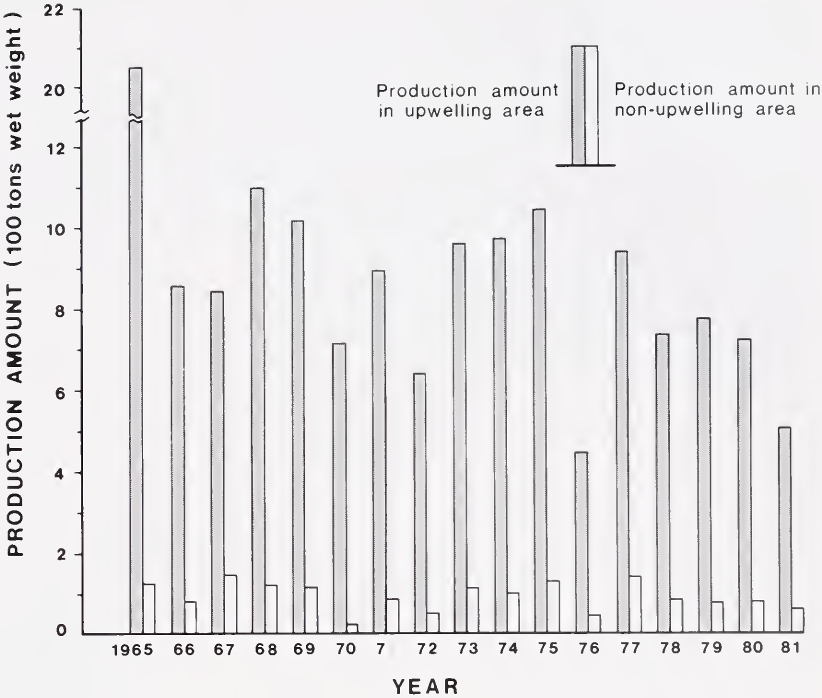
The chart on page 41 shows a comparison of yields of agar-agar (*Gelidium amansii*) in the upwelling region lying in the rear of Miyakejima Island and nearby non-upwelling regions. The upwelling region produced 10 times as much agar-agar as the non-upwelling region, due to the promotion of agar-agar growth induced by the upwelling of lower-layer water. Similarly, the upwelling area showed more than three times as much catch of abalone, which feed on agar-agar, and spiny lobsters as the control region. The upwelling region also contained a large amount of phytoplankton, which served to attract migratory fishes such as flying fish, yellowtail, and mackerel, thus forming a productive fishing ground.

Both our culture experiments and the surveys of natural upwelling regions suggested that artificial upwelling of deep seawater should be effective in promoting the production of seaweed and shellfish, and in creating good fishing grounds.

Three Utilization Concepts

In general, there are three categories of deep seawater utilization technology for biological production:

- *Land-Based*. By this method, deep seawater will be pumped to a land-based tank either continuously or intermittently, and its rich store of nutrients, low temperature, and freedom from pollutants will be used to culture and produce phytoplankton and



*A comparison of agar-agar (*Gelidium amansii*) yields in upwelling and non-upwelling regions off Miyakejima Island.*

seaweed that provide food for fish and shellfish; and to grow clams, shrimps, and fishes. This technology is especially suited to the stable production of fish feed, disease prevention for the organisms which are reared, prevention of water quality deterioration, and the regulation of water temperature. It should play an important role in cultured fishing and in the production of juvenile fishes.

- *Shallow Sea Bottom-Based.* This technology envisions the sprinkling of artificially-upwelled deep seawater onto shallow regions near beaches, to augment the production of seaweed, clams, and shrimps inhabiting those regions. The feasibility of this technology is suggested by the increase in the production of seaweeds such as agar-agar and shellfish such as the abalone (*Haliotis japonica*) in the shallow areas near the upwelling region off Miyakejima Island.
- *Open-ocean Regions.* This technology seeks to create artificial upwelling of large quantities of deep seawater, to be discharged to open seas, enhancing the primary productivity of the regions, and for creating areas for the growth of young fish, and producing fishing grounds.

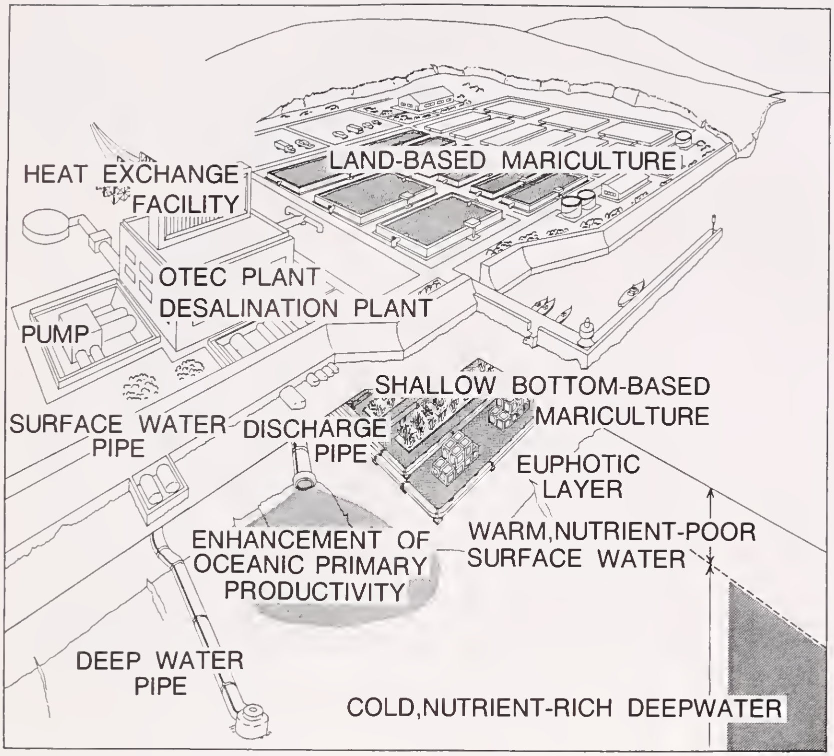
One concept being considered is the combination of a power plant and an aquaculture facility. The diagram on page 42 shows a conceptual plan for combining a deep seawater aquaculture facility and an ocean thermal energy conversion plant. Our trial calculations show that, assuming an intake volume of 230 tons per second, a 100-megawatt ocean thermal energy conversion plant, whose concept design is currently in progress, and the nitrate nitrogen concentration of 30 microgram atoms per liter found at a depth of 500 meters off Oshima Island, should be able to produce an equivalent upwelling condition in about 4 days.

Future Research

Judged from standpoints of technological effectiveness, required scale of technology, environmental impact, and the degree of technological risk involved, the development of land-based deep seawater utilization appears to offer the greatest promise among the three conceptual schemes identified.

Accordingly, JAMSTEC has upgraded its indoor phytoplankton continuous culture equipment with continuous inflow of deep seawater, undertaken research and development of beneficial phytoplankton production technology, and is in the process of conducting an engineering evaluation of deep seawater intake systems.

In a related development, the research and development of technology for beneficial use of deep seawater became a national project in 1986. JAMSTEC, in collaboration with other research agencies, including those engaged in fisheries research, will be conducting research and development of deep seawater utilization technology for the production of fishes and shellfish as well as for the phytoplankton that provides food for these organisms.



Concept of deep seawater mariculture facility combined with a power-generating facility.

Construction will soon begin on a land-based experimental upwelling plant (scheduled for completion in 1989), to which deep seawater will be supplied via intake pipes. At the present concept design stage, the plant will have the following features: depth of deep seawater intake, 250 to 300 meters; depth of surface intake seawater, 0 to 5 meters; volume of deep and surface seawater intakes, approximately 460 cubic meters per day apiece; and length of deep seawater intake pipes, 2,500 to 2,600 meters. The land-based experimental plant will have equipment for the rearing and experimental cultivation of fishes, shellfish, and fish-feed plankton, as well as facilities for water temperature and flow rate control.

One component receiving particular attention is the deep seawater intake pipes. Both technologically and economically, they are critical to the operation of the plant. Given the harsh marine conditions of Japan (for example, the common typhoons), it is essential that the intake pipes be low-cost, yet highly durable. Therefore, we are focusing on the design of the intake pipes and methods for their installation as priority tasks.

A Renewable Resource

The technology for the production of biological organisms through the use of deep seawater seeks to replicate, by artificial means, biological production found in natural upwelling regions, and to allow the efficient control and management of the production of beneficial organisms. Since deep seawater is a renewable resource, the development of a deep seawater utilization technology, working in harmony with the natural cycle, is expected to provide long-lasting benefits to mankind.

Both Takayoshi Toyota and Toshimitsu Nakashima are Assistant Senior Scientists in the Marine Research and Development Department at JAMSTEC.

Selected References

Nakashima, T. and T. Toyota. 1979. Report on fertility of the sea by utilizing deep seawater. *Technical Report of Japan Marine Science and Technology Center* No. 3: 117–125.

Ryther, J. H. 1969. Photosynthesis and fish production in the sea. *Science* 166: 72–76.

Toyota, T. and T. Nakashima. 1986. Properties of deep seawater—new resource for biological production. *Technical Report of Japan Marine Science and Technology Center* No. 16: 101–114.

Wave Power Generator *Kaimei*

by Takeaki Miyazaki

The wave power generating system "Kaimei."

Of the various forms of ocean energy available, the long, rugged coasts of Japan are particularly well-suited for generating wave energy. It also seems relatively easy to exploit. Based on our research at JAMSTEC, a number of approaches to wave power generation have been suggested. Of these, the one that offers the promise of earliest practical utilization is air turbine generation. Here, the wave energy is converted to a high-speed air flow within an air chamber installed on the water surface, generating power by rotating an air turbine.

We have constructed the large-scale wave power generator, *Kaimei*, which is 80 meters long, 12 meters wide, weighs some 800 tons, and provides 13 air chambers and 4 floating chambers. Open sea experiments were conducted in 1978, 1979, and 1985 during the winter months when waves were high. Air turbines were installed above the air chambers, and power was generated by a generator that was directly connected to the turbines. Phase I experiments conducted during the 1978–79 period demonstrated the feasibility of large-scale power generation, examined mooring safety, yielded a successful small-scale transmission of generated power to land-based facilities, showed similarity between open sea and test tank experiments, and resulted in successful international collaboration. These experiments, however, left unresolved the problems of low wave-energy conversion efficiency and high power-generating cost. Phase II experiments, including open sea experiments, conducted during 1985 were specifically designed to address these issues.

Principal elements of Phase II research included improvements on the air turbine, the development of air flow phase control methods, and achieving greater intensity of output. Research also was conducted on the design of an optimum ship profile and air chamber arrangement for improving overall output. These Phase II open sea experiments were carried out as a joint effort between Norway, Ireland, Sweden, Britain, the United States, and Japan under the title of the "IEA R&D Program on Wave Energy." The experiments were conducted 3 kilometers off Yura, Tsuruoka City, in the northeastern part of the Sea of Japan, over a water depth of 40 meters. The *Kaimei* ship was moored at the site by using 4 lines in the bow, and 1 line, provided with an intermediate buoy, in the stern. The stern mooring enabled the ship to swing, so that waves would always strike the ship at the bow, minimizing the force exerted on the mooring.

The conversion of wave motion to air flow presented some initial difficulties. The wave energy is converted to a high-speed air flow within an air chamber. However, since such an air flow involves a reciprocal air motion, early impulse turbines required the use of valves to force the air to flow in one direction. Although the amount of energy loss associated with valve motion was small, the technique was marred by frequent breakdowns of the valve hinges. To overcome this difficulty, we have developed a "tandem wells" turbine, which does not require a valve mechanism, and in which the turbine constantly rotates in one direction even if the air moves in a reciprocal pattern. We also are attempting to improve the conversion efficiency,

The tandem wells turbine.

particularly for low-frequency waves which tend to produce low wave-energy-conversion efficiency.

The open sea experiments of 1985 were conducted under wave conditions with a one-third significant wave height of 1.6 meters and a maximum wave height of 8.6 meters. The *Kaimei* carried a total of 5 turbines, 2 in the bow, 1 in the center, and 2 in the stern, plus 3 phase controllers and various types of measurement devices. The two turbines in the bow were valveless turbines; the one placed at the foremost position was a double reverse-rotation McCormick turbine designed and manufactured in the United States, and the second turbine was a "tandem wells" turbine. The remaining three turbines were all impulse turbines incorporated within four-valve power generators. The power generator for the "tandem wells" turbine had a capacity of 60 kilowatts, while the remainder had a capacity of 125 kilowatts each. In these experiments, the power generated was consumed in load resistors for the purpose of obtaining detailed records of the voltage and current generated.

The Phase II open sea experiments were completed without any significant problems, and the data obtained are currently being analyzed. Research into the design of optimal ship profile and air chamber arrangement is currently being pursued from both theoretical and modeling points of view. A conclusion that has emerged thus far is that a divided floating chamber ship profile offers the best performance. Current research efforts are aimed at establishing an optimal method for the design of *Kaimei*-type wave-power generators, based upon the results of ship profile studies and open sea experiments.

On the largest scale, it has been tentatively estimated that up to 50 percent of Japan's energy needs could be generated by this method. On a more modest scale, it may be that the greatest feasibility, and most competitive costs, will be on small islands and in isolated communities, where the normal electricity supply is from diesel-driven generators.

Takeaki Miyazaki is an Assistant Senior Scientist in the Marine Research and Development Department, JAMSTEC.

Recovery of Uranium from Seawater

by Hitoshi Hotta

The recent worldwide rise in the ratio of nuclear power generation to overall energy supply has led to an increase in demand for uranium, the fuel for nuclear power. Given that the total uranium deposits, both confirmed and estimated, contained in the land areas of the Western nations is about 5 million tons, demand is likely to outstrip the supply by the year 2010 with a sharp rise in cost, even if the practical use of fast breeder reactors is realized.

Does the answer to this problem lie in the oceans? Seawater contains approximately 3 parts per billion (some 3 grams per 1,000 tons of seawater) of dissolved uranium, with a worldwide total amount of more than 4 billion tons. An efficient, low-cost recovery of this resource would significantly contribute to easing the uranium supply problem. Although research is under way in West Germany, the United States, and in Japan, the low concentration of uranium in seawater, and the fact that large amounts of seawater must be processed to recover a given amount of uranium, impose considerable difficulties that must be resolved before uranium recovery from seawater can be put into practice.

A New Alchemy

One method of recovering uranium from seawater involves passing the seawater through columns containing an uranium adsorber. The seawater coming into contact with the adsorber is then adsorbed by means of ion exchange, and the enriched uranium adhering to the adsorber is eluted and concentrated to form a "yellow cake." Important elements in this recovery technology are the performance of the adsorber (in particular, the rate of adsorption), saturated adsorption capacity, the chemical and physical strength of the adsorber, cost, efficiency of the seawater inflow into the column, and the efficiency of water flow within the column. The Metal Mining Agency of Japan has been operating a test plant in Nio-Cho, Kagawa Prefecture, since April, 1986, designed to recover

10 kilograms of uranium per year. This plant uses hydrous titanium oxide as an adsorbent, and recovers uranium by pumping the seawater to a land-based plant. The cost of operating the pump, in addition to the costs related to the adsorber and plant operations, presently creates high overall recovery costs.

This problem calls for use of the energy inherent in ocean waves and currents as the power to drive the influx of seawater into columns containing an adsorber, and for providing adequate contact between the seawater and the adsorber. Since 1983, JAMSTEC, in cooperation with the Government Industrial Research Institute, has been pursuing research on wavepower-based uranium recovery from seawater. By this technique, a relative velocity is generated between the vertical velocity component of the orbital motion of the seawater near the water surface and the column placed underwater. The seawater enters the column through a mesh attached to the upper and lower ends of the column, and contacts the adsorber. We have named this the "wave energy utilization method."

Experiments based on this technology were conducted from 1983 till 1985 in the Japan Sea, 3 kilometers off Yura, Tsuruoka City, Yamagata Prefecture, during the summer. About one-third of the column volume of adsorbers, consisting of amidoxime chelating resins, were placed in either cylindrical or rectangular columns to which meshes were attached at the top and at the bottom. The columns were either suspended from buoys floating on the water surface, or affixed to an open well in the hold of a ship.

Amidoxime chelating resins are particle resins with an average particle size of 0.5 millimeters. Their great physical strength and ability to withstand repeated use make them well suited to application of the wave energy utilization method. However, to prevent a loss of the resins from the column, it is necessary to provide a mesh cover at the upper and lower ends of the column. This creates problems of a reduced seawater inflow and deposition of marine organisms on the mesh.

During 1983 and 1984, in the early experiments, we used vinyl chloride columns 9 to 35 centimeters in diameter and approximately 40 centimeters high. Approximately 0.1 to 4 liters of adsorbers were placed in these columns, and a variety of column forms were experimented with. During the experimental period, the seawater was about 25 degrees Celsius, with a low mean wave height of 0.4 meters. The columns were lowered to a position some 2 meters below the surface, to remain either suspended or affixed for 10 to 20 days. Initially, experiments were run by trial and error. However, after the optimum adsorber packing density and the combination of upper and lower column meshes were determined, the columns performed at a rate no lower than 0.07 milligrams of uranium adsorption per 1 gram of adsorber used per 10 days.

During 1985, a scaled-up version of the technique was used. A total of 500 liters of adsorber were placed in steel boxes each measuring 1.3 meters long, 0.5 meters wide, and 0.6 meters high. The boxes were attached below the water surface to the hold of a ship whose bottom plates had been removed, and were allowed to remain in that state for 109 days. The prevailing sea conditions were about the same as the conditions encountered during previous experiments, and an analysis of the adsorber

Advanced Robot Technology

An Advanced Robot Research Association was established in Japan in 1984. The association is comprised of 18 companies and 2 organizations, and serves as a focal point for research on the development of robots for work in nuclear power plants, in disaster prevention, and for support of ocean oil exploration, as well as other marine uses, such as unmanned submersibles. Japan is promoting the development of advanced robot technology through the Agency of Industrial Service and Technology, which falls under the Ministry of International Trade and Industry (MITI).

Robots are being designed and developed to perform sophisticated work activities, including maintenance, inspection, and repair of underwater oil exploration facilities. Among other research projects are position and navigation control devices for underwater cruising, underwater vision studies, the development of manipulation equipment, and supervisory control instruments.

Members of the Advanced Robot Research Association include: Ishikawajima-Harima Heavy Industries Co., Ltd.; Oki Electric Industries Co., Ltd.; Kawasaki Heavy Industries, Ltd.; Kobe Steel, Ltd.; Komatsu, Ltd.; Sumitomo Electric Industries, Ltd.; Toshiba Corp.; JGC Corporation; Japan Industrial Robot Association; NEC Corporation; Japan Power Engineering and Inspection Corporation; Hitachi, Ltd.; Fanuc Ltd.; Fujitsu, Ltd.; Fuji Electric Corporate Research & Development, Ltd.; Matsushita Research Institute Tokyo In-Corporation; Mitsui Engineering & Shipbuilding Co., Ltd.; Mitsubishi Heavy Industries, Ltd.; Mitsubishi Electric Corp.; and the Yaskawa Electric Mfg. Co., Ltd.

Readers desiring additional information should contact:

Advanced Robot Technology
Research Association
Kikai Shinko Kaikan 2-kai
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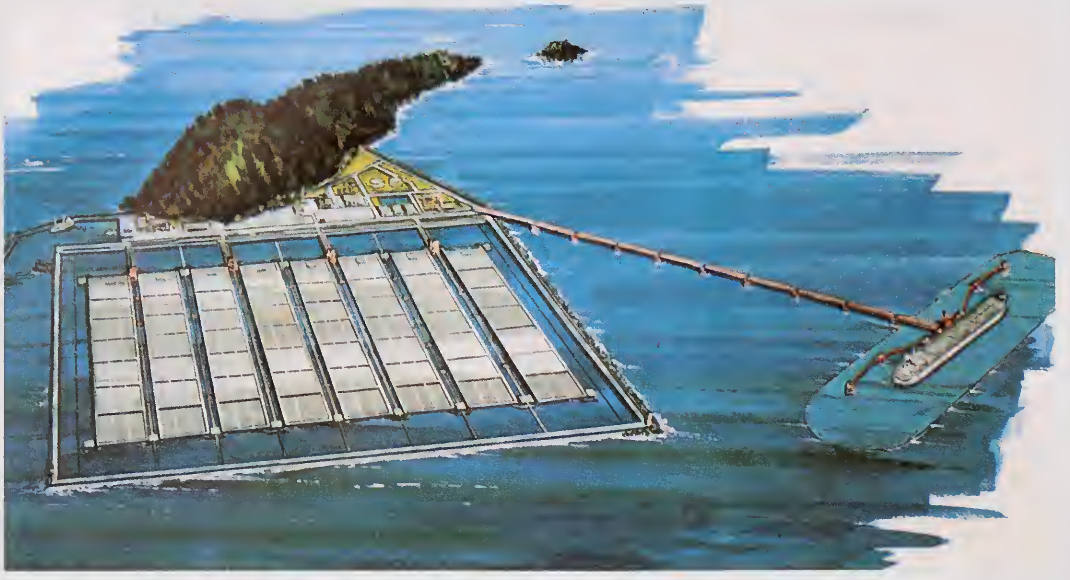
Oil



Petroleum is Japan's major energy source, and oil consumption in the country has increased greatly. Although Japan imports almost all of its oil, the country, the world's third largest consumer, is actively involved in exploration, stockpiling, R&D, and investment. One important and principal agency is the Japan National Oil Corporation (JNOC). Established in 1967, this independent government body is responsible for promoting and expanding oil exploration and stockpiling by Japanese companies.

JNOC-assisted companies explore, develop, and produce both onshore and offshore. Offshore sites include China, Indonesia, the Middle East, Africa, the North Sea, the United States, and Canada. Geological and geophysical surveys by JNOC are conducted throughout the world's oceans, including Antarctica.

Like most countries, Japan has a stockpiling program. Much of it is underground, or in tanks. A recent innovation is the development of floating stockpiling bases.

The Shirashima Base, in the offshore area of the Wakamatsu ward in Kitakyshu City, consists of eight large box-type storage vessels surrounded by anti-leak banks. When completed in 1991, the storage capacity will be 5.6 million kiloliters (1.5 billion gallons). A similar project, scheduled for the Kamigoto area in the Minami-Matsuura Province of Nagasaki Prefecture, will have a storage capacity of 4.4 million kiloliters (1.2 billion gallons). Its completion is scheduled for 1988.

—JHWH

Above, concept drawing of the Shirashima Base—a floating oil stockpiling system. (Courtesy Japan National Oil Corporation)

showed about the same adsorption performance as achieved previously.

Problems and Optimism

These experiments have confirmed the feasibility of uranium recovery from seawater using wave energy.* However, a number of significant problems still remain to be resolved, including enlarging the scale of the technology, preventing the deposition of marine organisms, and improving adsorber performance. As for adsorbers, agents capable of adsorbing scores of times as fast as those used in our experiments have been developed recently. If similar progress is made in other critical areas as well, the practical utilization of the technology will materialize.

Hitoshi Hotta is a Research Engineer, Marine Research and Development Department, JAMSTEC.

* Recently, the cost of mined uranium has fallen to about

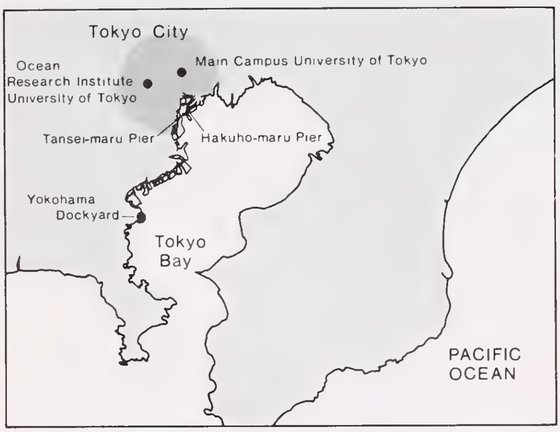
Uranium recovery experimental columns (1984).

Installation of enlarged uranium recovery experimental columns (1985).

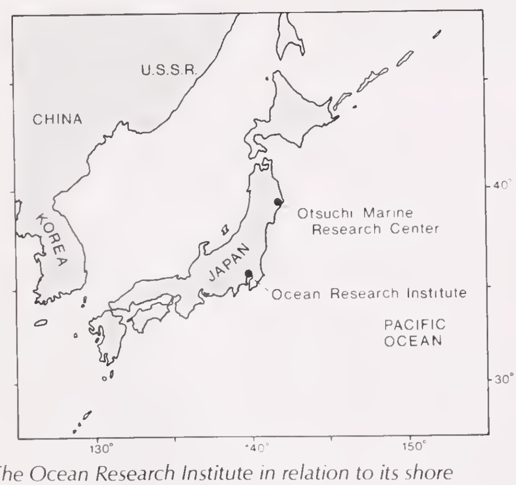
US$17-22 per pound. Against this, we estimate that, using a large-scale, wave-energy device, with a capacity of recovering 1,000 tons of uranium from seawater per year, the price of the recovered uranium would be about US$80 per pound. It is therefore clear that world uranium prices bear strongly upon this technology.

Japan's Ocean Research Institute

by Takahisa Nemoto



Location of Ocean Research Institute in Tokyo and dock sites for institution ships.



The Ocean Research Institute in relation to its shore laboratory.

The Ocean Research Institute (ORI), which is part of the University of Tokyo system, was founded in April 1962 by an Act of the Japanese Diet. During the years preceding its foundation, Japanese marine scientists had emphasized the necessity of establishing a new oceanographic institution for the promotion of basic and comprehensive research in the marine sciences. In 1958, the Science Council of Japan passed a resolution at its General Assembly stating that such an institute should be established, and recommended its formation to the Japanese Government. In response to this recommendation, the Government decided, four years later, to appropriate the necessary funds for the establishment of the institute at the University of Tokyo. Today ORI is the core institute for marine sciences in Japan, and in many ways is similar to both the Woods Hole Oceanographic Institution and the Scripps Institution of Oceanography in America.

The institute presently has 15 research divisions equipped with research instruments and facilities on the Nakano Campus, and a shore laboratory, the Otsuchi Marine Research Center, in Otsuchi, Iwate Prefecture. The institute operates two research vessels, the *Tansei-maru* and *Hakuho-maru*, under the auspices of the Ministry of Education, Science, and Culture. Institute facilities are open to the use of marine scientists throughout the country, and often serve in the implementation of international cooperative research projects. Expertise in physical, chemical, and biological oceanography, meteorology, geology and geophysics, marine biology, and fisheries is provided for more than 50 graduate students at the master's and doctorate levels. About 7,000 to 8,000 researchers in total, including scientists and students from all over the world and a faculty of more than 60 ORI scientists, are involved each year in the institute's various research efforts.

The Ocean Research Institute, University of Tokyo, Nakano Campus.

Most of the operating budget of the Ocean Research Institute is funded by the Ministry of Education, Science, and Culture. From a total budget of Y330.8 billion (~US$2 billion) for the promotion of scientific research in 1986, ORI was allocated Y2.4 billion (~US$15 million) for its general budget, and an additional Y98.5 million (~US$615,000) for research grants. In general, the budget for the support of ocean sciences is steadily increasing in Japan.

Institute Research Activities

Physical oceanography. The ultimate goal of our research efforts lies in clarification of the following three matters: the structure of the general circulation in the world ocean and the mechanism of its fluctuations; the global features of oceanic tides and their influence on related phenomena; and the processes and mechanisms of large-scale ocean/atmosphere interactions. For logistical reasons, our observational efforts are principally in the North Pacific.

Marine meteorology. The atmosphere and the ocean interact with each other in various ways and on different scales. An eventual objective in our meteorologic studies is to understand the mechanisms of these interactions.

Submarine geophysics. Research in this area is aimed at understanding crustal and subcrustal structures under the oceans. This involves marine geodetic and marine geophysical studies based on gravity measurements; measurement of geomagnetism and its geophysical interpretation; geodetic studies by satellites; and development of equipment and studies of methodology for marine geophysical research.

Submarine sedimentation. In this area, geological processes occurring on the ocean floor, and the nature of the basement of the ocean floor are studied to advance our knowledge of marine geology and to obtain a clearer understanding of the Earth. Research activities primarily center on studies of sedimentary structures by multichannel seismic reflection profiling, sedimentation processes, and the geological setting of marine mineral resources.

Ocean floor geotectonics. Studies of the structure and evolutionary history of the ocean floor are carried out in this division of the institution. The nature of oceanic sediments, basaltic rocks, and mantle rocks are studied, as well as the processes of their formation. Measurements are made of the magnetization of Ocean Drilling Project piston cores and determinations are made of geomagnetic field variations, ocean floor spreading, and sedimentation rates. The evolutionary history of island arcs is also studied along with the rheological (deformation and flow) properties of mantle rocks and sea-level changes on oceanic islands.

Marine inorganic chemistry. This division aims at clarifying the distribution and circulation of various components within the oceans and through the lithosphere-oceans-atmosphere system. Research on the geochemical evolution of the ocean is included here. Special emphasis is placed on submarine volcanism and hydrothermal activities; and development of analytical techniques.

Marine biochemistry. The distribution and circulation of carbon, nitrogen, phosphorus, sulfur, and silicon in the sea are regulated by the activities of various kinds of organisms. These elements are present in volatile, dissolved, or suspended form, and thus their biogeochemical cycles in the sea are closely associated with those in the atmosphere and lithosphere. Because of its large capacity, the sea plays a crucial role in maintaining the global cycles of these elements. Research in this division is concerned primarily with the dynamics of these biologically-active elements in marine environments.

Physiology of marine organisms. Scientists in the Laboratory of Physiology of Marine Organisms focus their attention on the resolution of adaptive mechanisms of many and diverse marine life to various environments. Present studies pay special attention to the relations among fish migration, osmoregulation, and reproduction. Several scientists are working on the adaptation of marine plankton to environmental conditions of varying light intensity and nutrient availability.

Marine ecology. Researchers in this field seek an understanding of the structure and function of bottom ecosystems in each of the biogeographical regions that occur in the range from tropical waters to arctic seas. In general, research is concerned with the biological aspects of benthic organisms such as their biogeographical and ecological distributions, life forms, and life histories, as well as with interdisciplinary studies of regional ecosystems.

Marine planktology. This division is concerned with ecological and physiological studies of such things as the distribution, production, and temporal variations in density of plankton and micronekton in the sea. The role of plankton in the function and structure of the marine ecosystem is also studied. Present projects include: biological production in the ocean; biology of key species of plankton; blooms, mass propagation of plankton, and red tide phenomena; experimental studies on plankton and micronekton; and biochemical studies on plankton.

Marine microbiology. Two research projects, ecological studies of marine microorganisms and microbiological and chemical studies on the process of decomposition of organic matter in the sea, hope to clarify the physiological and ecological characteristics of marine bacteria and allied microorganisms. These studies also hope to understand their roles in the process of biological production as well as the cycles of various chemical species (carbon, nitrogen, and phosphorus) in the sea.

Population dynamics of marine organisms. This division is concerned with studies on the population dynamics of marine organisms, and related subjects, such as assessment, management, and prediction of exploited fish stocks. Studies are conducted both for the development of theories and methods, and for the purposes of practical application.

Biology of fisheries resources. Biological problems related to fisheries resources in marine ecosystems are studied in this division. The research projects in progress are: biology of marine sessile animals, taxonomical and ecological studies of elasmoblanchs, physiological and ecological studies of "ayu" (a freshwater smeltlike fish considered a delicacy), life histories of fishes; and the ecology of marine turtles.

Fisheries oceanography. Structures and their variabilities in oceanographic environments are investigated to establish a basis for the forecasting and management of fisheries. For this purpose, investigations are focused on the factors governing the distribution and movement of marine biological resources in fishing grounds, such as the distribution of nutrients and food as well as physical oceanographic structures and their fluctuations, including currents, fronts, and thermoclines, and year-to-year variations in oceanographic conditions in and around spawning grounds, and the processes of transport and dispersion of different types of drifters as well as eggs and larvae.

Fisheries ecology. Eventual objectives include the development of techniques to estimate the abundance of fishes and micronekton. Also, research is carried out to understand the mechanisms influencing stock size of these organisms. Other activities include: studies of systematics and ecology of fishes, studies of the early life history of fishes, application of hydro-acoustic techniques to estimations of fish abundance and behavioral studies, development of an underwater observation system, analysis of the schooling behavior of fish, and studies on the efficiency of fishing gear.

International Cooperation

The Ocean Research Institute coordinates many international programs. In the 1960s, two ORI research ships were involved in Cooperative Studies of the Kuroshio (CSK) Current and the International Biological Program (IBP). At present, the institute is heavily involved with the WESTPAC Program of the International Oceanographic Commission.

Many Japanese scientists presently are also involved in the Ocean Drilling Program using the

Japanese Antarctic Activities

The Japanese are conducting three major research projects in Antarctica. Upper atmosphere physicists and meteorologists are participating in the Middle Atmosphere Program (MAP); glaciologists and geologists, in the East Queen Maud Land Research Program; and biologists, in the Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS). All these programs are international in scope.

The Middle Atmosphere Program research is conducted at the Syowa Station, located at 69 degrees 00 minutes South and 39 degrees 35 minutes East, on Ongul Island, Prince Harald Coast. Observations of active auroras and the Earth's geomagnetic field have been conducted at the station since 1957. In the MAP program, upper atmosphere physicists and meteorologists are studying the middle atmosphere in the altitude range of 10 to 120 kilometers by means of remote sensing techniques, including satellites, aircraft, balloons, and sounding rockets. The dynamics, energetics, and structure of the middle atmosphere are monitored on the ground by laser radar, infrared spectrometer, and VHF doppler radar.

Japanese glaciological activities are concentrated in the areas of Enderby Land and Queen Maud Land. Most of this research is conducted from the Syowa Station and Ongul Island and the Mizuho Station in the Mizuho Plateau.

In 1982, Japan began a five-year glaciological program in conjunction with the International Antarctic Glaciological Project. During this period, drainage from the Shirase Glacier was investigated and subsequently the glacier was found to be unstable.

More than 5,500 meteorites have been collected from ice fields near, and in, the Yamoto Mountains, the Belgica Mountains, and South Victoria Land. These are stored at the National Institute of Polar Research in Japan.

Natural earthquakes monitored at the Syowa Station aid in the determination of Southern Hemisphere epicenters, the seismicity of Antarctica, and crust structure of the Antarctic continent. In addition, upper mantle and crust structures in the vicinity of the Syowa and Mizuho stations and the Southern Ocean are studied by means of gravity survey, airborne geomagnetic survey, and explosion seismology. Paleomagnetic studies of Precambrian-Cambrian (600 to 400 million years ago) rocks are also taking place.

Japan conducts a number of biological programs in the Antarctic, mainly at the Syowa Station. These include studies of mites found in moist sand and in green alga despite the generally harsh conditions of the environment.

Since 1982, Japan has been a member of Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS), which was started in 1977. Year-round samples are taken of phytoplankton, zooplankton, and fish, as well as of seawater for its chemical content. Studies also are made of the microorganisms that live in sea ice to determine their role as primary producers in the coastal ecosystem.

A number of Japanese government agencies form what is known as the Japanese Antarctic Research Expedition (JARE), which falls under the Ministry of Education, Science, and Culture and which takes the lead in coordinating Antarctic research. The vessel Shirase*, commissioned in 1983 and operated by the Japanese Maritime Self-Defense Force, is dedicated to research in the Southern Ocean.*

Anywhere from 36 to 47 scientists and technicians are usually stationed at the Syowa Station. A smaller contingent is usually present at the Mizuho Station, which is located at 70 degrees 42 minutes South, 44 degrees 20 minutes East at an elevation of 2,230 meters on the Mizuho Plateau.

Joides Resolution drill ship under arrangement with ORI. From 1977 to 1986, the institute also has worked with the National Institute of Polar Research in its BIOMASS Project in the Antarctic. The *Hakuho-maru* served as the flag ship for three other polar research vessels in this project. The results and data from these international expeditions will be presented during a symposium to be held at the Alfred Wegener Institute in West Germany in 1989. Other international projects, such as the Global Atmospheric Research Program (GARP) and its subprogram Monsoon Experiment (MONEX) have also utilized the institute's research ships.

In recent years, Japan and France have conducted research on subduction zones near Japan. An international symposium on this research was held in Tokyo and Shimizu in November of 1986.

Besides these projects, other international programs, such as the World Ocean Circulation Experiment (WOCE) (see *Oceanus*, Vol. 29, No. 4) are now in progress at the institute.

The Otsuchi Marine Research Center.

Our Shore Laboratory

The Otsuchi Marine Research Center was established in 1973 at Akahama, Otsuchi, Iwate Prefecture. This center has been open to the use of visiting scientists, including guests from abroad, since 1979. The center is located on the northern shore of Otsuchi Bay in the northeastern part of the island of Honshu. The Tsugaru Warm Current flows along the coast from the north, and the Oyashio and Kuroshio meet off the coast.

The center consists of a three-story main building, a two-story dormitory for 20 visiting scientists, a warehouse, and 30 outdoor culture tanks. The main building houses five laboratories for research in physical, chemical, geological, and biological oceanography, and fisheries science, a radioisotope laboratory, an experimental aquarium room, culture rooms regulated to temperatures of 5, 15, and 25 degrees Celsius, five constant temperature rooms, five research rooms for scientists, a library, a meeting room, a workshop, and an administration office.

Two hundred tons of filtered seawater are supplied to the tanks and laboratories each hour. Three lines of running seawater of up to two tons an hour with temperatures controlled in the range of 8 to 27 degrees Celsius are available in the experimental aquarium room during all seasons.

The center is equipped with a variety of specialized apparatus, including current meters, a long-wave recorder, seawater temperature recorders, an STD salinometer, spincotype ultracentrifuges, electron and scanning electron microscopes, a data analyzer, and an underwater TV and VTR. It also has three research boats, the *Yayoi* (16 tons) with a winch and echo sounders; the *Rias* (2.2 tons); and the *Challenger* (1.0 ton).

The investigations carried out by the research center embrace a wide variety of fields in marine science, including physical oceanography, submarine geophysics and sedimentation, marine chemistry, biology, and fisheries science. The main studies at present concern population genetics and evolution of marine organisms; ecological and endocrinological studies on behavior and adaptation during seaward migration of chum salmon fry; taxonomical, ecological, and physiological properties of the aerobic photosynthetic bacterium *Erythrobactor*; chemical interactions between marine sediment and seawater, through dissolution and absorption of inorganic and organic substances; and the structure and variability of the Tsugaru Warm Current off the Sanriku coast.

Research Vessels

The institute's two research vessels, *Tansei-maru* and *Hakuho-maru*, have proved indispensable for research activities.

The old *Tansei-maru* ended her service on 15 October 1982. Since her maiden voyage on 20 June 1963, the *Tansei-maru* had completed 399 scientific cruises around Japan by October 1982.

The new *Tansei-maru* began service in October 1982, and has already logged many scientific cruises. The diesel-powered vessel is 51 meters long, 9.2 meters in the beam, and displaces 469 gross tons. A party of 11 scientists can be accommodated. She is equipped with a 7,000-meter hydrographic winch, a 7,000-meter deep sea winch, a 4,000-meter CTD (Conductivity, Temperature, and Depth) wire, and a large A-shaped stern frame.

The *Hakuho-maru* was completed in March 1967. She is 95 meters in length, has a 15-meter beam, displaces 3,200 gross tons, and has a range of 15,000 miles. She can accommodate a scientific party of 32 members. Diesel-electric powered, she is equipped with twin screws, twin rudders, bow steering machinery, and an anti-rolling tank for

Top ORI Research Priorities

Asked to list the top research priorities of the last five years, the Director of the Ocean Research Institute, Takahisa Nemoto, responded:

- *Modelling of airmass transformation processes over the ocean. Numerical models have proven helpful in studying the interaction between small-scale cumulus convection and large-scale air flow, as well as explaining the transformation process of continental cold airmasses flowing over warmer seas.*
- *The study of local wind systems in the Kanto district (the central region of Japan). The structures of local wind systems, including land and sea breeze systems and mountain and valley breeze systems, and their diurnal variations are examined using observational data. By taking into account their long-range transport by local winds as well as their chemical reactions, the mechanisms of high concentrations of air pollutants are being better understood.*
- *Understanding the geologic evolution and processes of the Japanese arc-trench system. These include trench sedimentation, accretionary processes, trench tectonic erosion, the role of fluids in a subduction zone, volcanic evolution, the rifting process of back-arc basins, and hydrothermal activity.*
- *Detailed mapping of gravity in the subduction zone around the Japanese Islands, geomagnetic study of the seafloor using ocean-bottom magnetometers, and the study of the marine geoid (a surface of constant gravitational potential) on the basis of satellite altimeter data.*
- *Investigation of the tectonic structure and petrology of the fore-arc zone along deep-sea trenches in the western Pacific, which has revealed the occurrence of an ophilitic suite composed of ultramafic rocks, basaltic intrusives, basaltic lavas, and sediments in the toe zone of the Izu-Bonin (Ogasawara) Trench.*
- *The study of the aerial distribution and vertical structure of oceanic magnetic anomaly lineations, particularly in the marginal basins of the western Pacific, and the measurement of magnetic anomaly lineations in the Japan Sea Basin and other back-arc basins. (The first detailed survey of magnetic anomalies in the Japan Basin was made by the* Hukuho-Maru *in 1986).*
- *Understanding the process of nitrogen cycling in the oceanic waters of the North Pacific. Phytoplankton in the oligotrophic open oceans are, in general, not nitrogen-depleted, and ammonium serves as the main source of nitrogen.*
- *The study of phosphorus metabolism in coastal waters. When the abundance of surrounding inorganic phosphorus exceeds their demand, phytoplankton take up and store phosphorus within their cells. Orthophosphate serves as a phosphorus reserve in diatoms and polyphosphate in flagellates.*
- *Studies of the initiation mechanism of sperm motility in fishes.*
- *Establishment of the biology of micronektonic fish (*Cyclothone *spp.) and shrimps.*
- *Investigation of the ecological implications of marine bacteria that produce biologically active substances in marine biological communities, as well as their practical application in biotechnology.*
- *Analysis of the structure of bacterial population in various environments. For the ecological group, Vibrionaceae, horizontal and vertical distribution of different species among various areas was determined, and their role in the degradation process of organic matter was examined.*
- *Studies on parasitic copepod fauna and the biology of* Pseudomyicola spinosus, *associated with the blue mussel,* Mytilus edulis galloprovincialis.
- *The development of methods for analyzing the length or age-at-capture of sperm whales in the northwest Pacific, and minke whales in the Antarctic Ocean.*
- *Studies of physical and environmental oceanography on tide-induced residual currents; density currents and accompanying fronts; and wind-driven currents in estuaries, bays, and shelf regions.*

maneuvering for scientific operations. She contains several navigation systems—including NNSS (Navy Navigation Satellite System), Auto Loran C, radar (2 systems), Decca, and a NOAA meteorological satellite receiver. She has a 10-ton crane, and 10 winches, including a 14,000-meter tapered winch wire for heavy duty work, and two winch wires that can transmit electric codes for equipment, such as CTD instruments. The *Hakuho-maru* also houses two large and seven smaller laboratories for scientific research.

At present, the institute is planning to replace the *Hakuho-maru* with a new, bigger, research vessel of 3,980 gross tons, measuring 90 meters long and 16 meters in the beam—equipped with such options as a biological resources probing system, a satellite data reception device, and a narrow Sea Beam bottom profiling system. Various laboratories will be built inside the ship. These will include a germ-free room for chemical analyses, another such area for studies of microorganisms, and a radioisotope lab for studies of physiological activities and metabolism of ocean plants and animals.

Growth Seen From Challenges

Almost all the professors at the institute are members of the Graduate School of the University of Tokyo. The faculties of the Graduate School of which the institute staff are affiliated are the faculty of Science (Geophysics, Chemistry, Biochemistry, Zoology, Botany, and Geology) and Agriculture (Fisheries).

In addition, the institute accepts foreign research students and research fellows in every division. Students from many countries from all over the world have studied at the institute.

The basic purpose of the institute is to conduct research directed toward a better understanding of the complex problems of marine science. Research and education demands on the institution continue to grow. Our work will grow as we strive to meet these challenges.

Takahisa Nemoto is Director of the Ocean Research Institute in Tokyo.

Research Vessel Tansei-maru.

Research Vessel Hakuho-maru.

Letter Writers

The editor welcomes letters that comment on articles in this issue or that discuss other matters of importance to the marine community.

Early responses to articles have the best chance of being published. Please be concise and have your letter double-spaced for easier reading and editing.

The Hydrographic Department

The Hydrographic Department of Japan carries out mapping surveys and makes oceanographic, astronomical, and geological observations as part of its prime function.

The department publishes nautical charts and other hydrographic publications, including sailing directions, tide tables, and nautical almanacs. It also issues Notices to Mariners (navigational warnings), publishing information on harbor construction, wrecks, and other hazards to navigation.

Just recently (1983), the Hydrographic Department, which was founded in 1871 as part of the War Department under the Navy and which was transferred in 1948 to the Maritime Safety Agency, has begun observations on marine pollution and submarine volcanic activities. It is now taking part in the national program for earthquake prediction. Department officials feel that these activities are as important or more important than the department's traditional map-making functions.

Marine Pollution and

The view from Mt. Washu, in Okayama Prefecture, looking south over the Seto Inland Sea.

Countermeasures in Japan

by Masamichi Murakawa

Japan is surrounded by the sea and bordered by many beautiful bays and beaches. Its bordering seas abound with marine life. But during Japan's rapid economic growth of the 1960s and 1970s, pollution of the sea surrounding Japan increased. Coastal fisheries were damaged severely and some bathing beaches were closed. To cope with these problems the government instituted monitoring of seawater

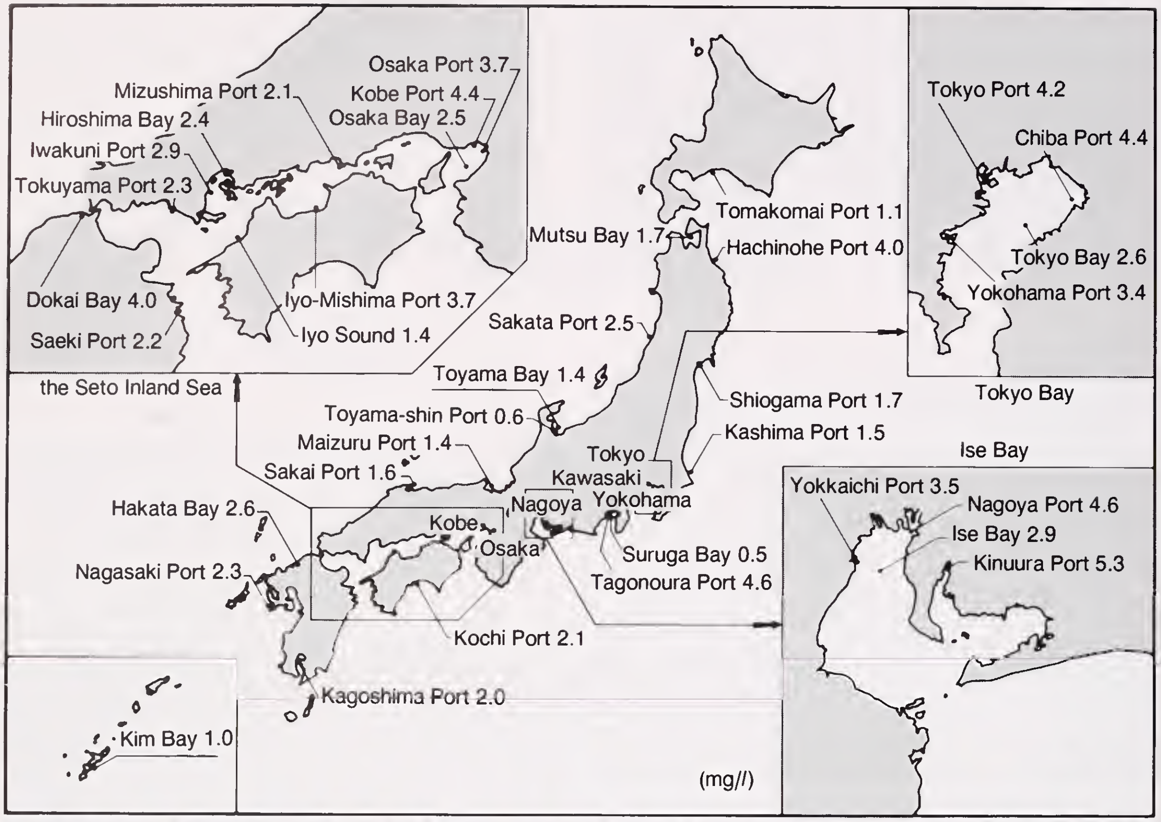


Figure 1. Average chemical oxygen demand (COD), a common pollution indicator, for the main bays and ports of Japan in 1984.

quality, and began various countermeasures to combat pollution. As a result, water quality has generally improved.

Monitoring System

Monitoring of seawater quality in Japan is executed primarily by the nation's 47 prefectures. Some 2,200 points are monitored, almost all within 10 kilometers of the coast. Water samples are drawn 6 to 24 times a year at each point and tested for cadmium, cyanide, organic phosphorus (from agricultural chemicals), lead, chromium (hexavalent), arsenic, total mercury, alkyl mercury, polychlorinated biphenyls (PCBs), acidity (pH), chemical oxygen demand (COD), suspended solids (SS), dissolved oxygen (DO), coliform bacteria, total phosphorus, total nitrogen, and others.

Among these items the most important is COD, which indicates the amount of organic matter in seawater.

Technically, the value of COD is the weight of the oxygen equivalent to the amount of the oxidizing substances consumed by the organic substances in the water during testing. A larger numerical value of COD means that the seawater contains more organic substances. Although potassium dichromate ($K_2Cr_2O_7$) is used as the oxidizer for COD measurement in Europe and America, potassium permanganate ($KMnO_4$) is used in Japan. The value obtained for COD through the Japanese method is usually a little smaller than that obtained through the former method.

Seawater Quality

Among the items mentioned previously, such hazardous substances as cadmium, cyanide, and organic phosphorus are present in negligible quantities. But the problem of pollution by organic substances is serious, particularly in the main bays and ports (Figure 1). The most severely and broadly polluted areas are Tokyo Bay, Ise Bay, and Osaka Bay. As these bays are semi-enclosed, the pollutants carried into them by rivers are prone to accumulate. In addition, some of Japan's most densely populated cities are located around these bays—Tokyo, Kawasaki, Yokohama, Nagoya, Osaka, and Kobe. The areas encircling these bays are also the main industrial districts in Japan. Only a few other bays and ports show such a high COD level, and their area is very small. In the open sea, COD is about 1 milligram per liter. At Kim Bay in Okinawa, one of the cleanest bays in Japan, it is 0.7 milligrams per liter. In Tokyo Bay, on the other hand, the summer value of COD exceeds 5 milligrams per liter for about half the bay (Figure 2). It is especially high in the inner part of the bay, over 9 milligrams per liter. In winter, the value of COD drops to less than 5 milligrams per liter. This difference is caused by a

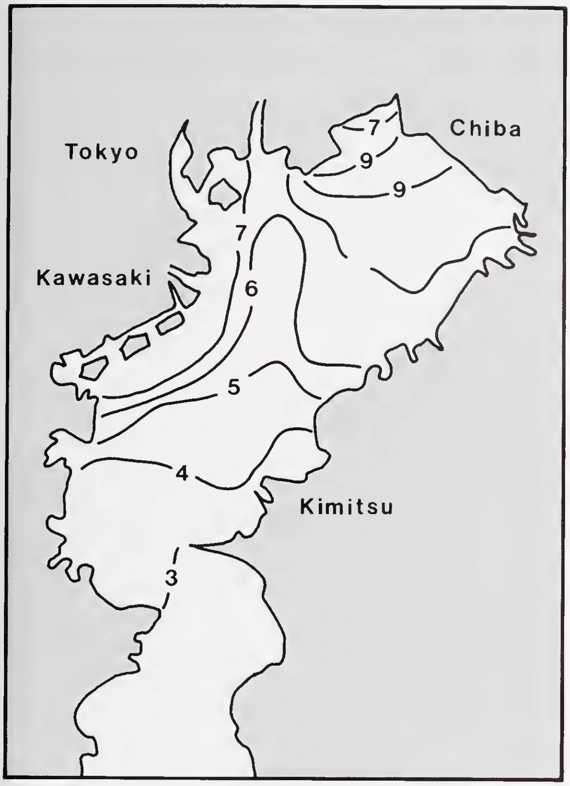


Figure 2. Summer concentrations of COD in Tokyo Bay in 1984. COD values are in milligrams per liter.

remarkable increase in the amount of phytoplankton present in summer. As the sampled water is not filtered before measurement, the plankton are oxidized by the oxidizer and raise the value of the COD.

Red Tides and the Seto Inland Sea

Another heavily polluted area is the Seto Inland Sea (Figure 3). This inland sea was once so beautiful that it was designated a national park, but it was severely polluted during the years of high economic growth. The most polluted part of the Inland Sea is Osaka Bay, where COD exceeds 5 milligrams per liter.

The Seto Inland Sea also has become eutrophic (nutrient rich) because of the great amount of nutrients flowing into it, and red tides occur widely every year. In 1972, 1977, and 1978 many cultivated "hamachi" (a juvenile yellow-tail jack) died from red tides. The damage in 1972 amounted to 7.1 billion yen. Such great damage has not been reported recently, but some fish and shellfish die every year (Figure 4). As the monitoring systems were established, the number of red tide cases reported in 1976 was 326. Since then the number has decreased, but even now about 200 red tide cases are reported every year, of which about 10 cause some damage to the fisheries. The main plankton that cause these red tides are *Skeletonema costatum*, *Noctiluca miliaris*, *Chattonella antiqua*,

Marine Biological Stations in Japan

There are 22 marine biological stations dotting the coastlines of Japan. Each station is affiliated with one of the national universities as an educational and research facility. Many Japanese biologists begin their studies of the animal kingdom and algology at these stations.

The first marine station in Japan was established in 1885 at Misaki. Today the stations stretch from Hokkaido in the north to Okinawa in the south, encompassing cold, temperate, and subtropical seas (see map page 5).

Students from more than 60 universities work at these stations, which also see visits from many foreign students.

This writer visited the Sugashima Marine Biological Laboratory, which is located on the west coast of Sugashima Island in Ise Bay, some 3.3 kilometers east of Taba-shi in the Mie Prefecture (about 4 hours by fast train from Tokyo).

Founded in 1939 and renovated in 1970, the original purpose of the laboratory was to provide courses in marine biology, such as invertebrate zoology, developmental biology, and optics for students in the School of Science at Nagoya University (some 135 kilometers away). However, now the station is host to many visiting foreign students and scientists on a year-round basis.

The laboratory, run by Dr. Hidemi Sato, who trained at the University of Pennsylvania, focuses on sea-urchin embryology because of the abundant supply of the animals in the waters nearby, which are generally rich in many types of fauna and flora.

The interests of staff members at the station include the mechanism of cell division, the development of marine invertebrates, membrane physiology of oocytes and eggs, and the biophysics and biochemistry of the cytoskeleton.

The laboratory itself consists of a two-story research building, comprising more than 1,000 square meters of floor space, a dormitory, and two cottages. The station has two small boats for field work, which also serve as ferries to and from the resort town of Toba, known for its pearl museum and diver exhibitions.

Researchers desiring information on opportunities at any of the Japanese research stations can write for the very complete booklet, National Marine and Inland Water Biological Stations in Japan, *to:*

Dr. Masao Yoshida,
Director
Ushimado Marine Laboratory
130-17 Kashino, Ushimado
Okayama-ken 701-43, Japan

—PRR

Floating Tars

Japan is not exempt from the hydrocarbon pollution that exists in other parts of the world. In a 1986 paper by S. Takatani, T. Sagi, and M. Imai, in The Oceanographical Magazine, *Vol. 36, the surface distribution and seasonal variation of floating tars and petroleum hydrocarbons in the seas adjacent to Japan and in the western North Pacific are reported. Monitoring by the Japan Meteorological Agency since 1977, shows that the Kuroshio (the main oceanic current off Japan—a counterpart to the Gulf Stream) and its countercurrent are extensively polluted with floating tars. Summer levels are highest, and it is believed that the floating tars are transported to the south in winter by the northwest monsoon. The sea routes toward the industrial zones near Tokyo and Osaka, with the possible discharges of huge tankers, are identified as likely sources.*

The study showed low pollution levels in the seas directly east of Japan, and in the East China Sea. In the Okhotsk Sea, few or no floating tars were found. An additional encouraging note is that floating tars have generally decreased since 1981.

The monitoring of floating tars and petroleum hydrocarbons at the surface in the western North Pacific is an ongoing project of the Japan Meteorological Agency.

—JHWH

Heterosigma akashiwo, and *Gymnodinium sanguineum*; the latter three sometimes damage fisheries. Most red tides occur in coastal areas but they can be found throughout Osaka Bay where the concentrations of phosphorus and nitrogen are higher than in other areas of the Inland Sea.

Phosphorus is one of the nutrients that cause eutrophication. Each prefectural office around the Seto Inland Sea in 1980 established guidelines for the reduction of phosphorus discharge from various sources in the hinterland to reduce eutrophication. The most effective countermeasure among these guidelines is the switch from "detergent with phosphate" to "detergent without phosphate." When "detergent without phosphate" came onto the market, the prefectural offices appealed to the public to use it. The rate of use of the non-phosphate type rose from 55 percent in 1980 to 94 percent in 1984.

Environmental Quality Standards

To evaluate environmental quality, the government has established environmental quality standards for air, noise, and water. The standards for water are divided into two sections: those standards intended to protect human health, and those intended to protect the living environment (Table 1).

The standards applying to human health are applied nationwide. Those intended to protect the living environment are separated into three categories for sea area: A, B, and C. A given area is classified into one of these categories depending on its intended use. Most areas of open ocean are classified as Category A, with Categories B and C being applied to relatively polluted areas, such as ports and the inner parts of some bays.

With respect to COD, for example, the 75th percentile value for each sampling point is compared to the standard for that point. (Suppose seawater is sampled 12 times a year, the 75th percentile value is the ninth value from the lowest among the 12 values.) If the 75th percentile value at all points in the area meets the standard, the area is said to have achieved its environmental quality standard. Within broader geographic areas the number of locations achieving the standards is compared to the number of locations to which the standards apply to obtain an achievement ratio (Figure 5).

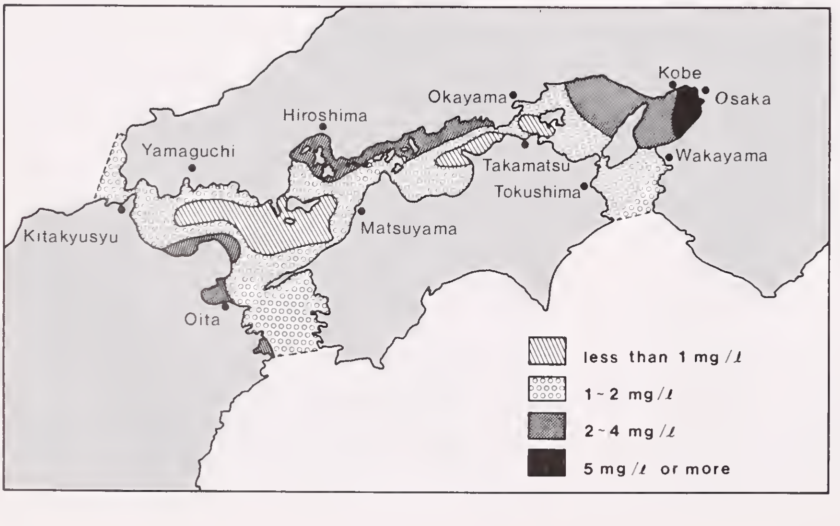


Figure 3. COD concentrations in the Seto Inland Sea during the summer of 1983.

Table 1. Environmental quality standards for seawater.

(1) Standards relating to Human Health

Item	Standard values[1]
Cadmium	0.01 mg/l or less
Chromium (hexavalent)	0.05 mg/l or less
Cyanide	Not detectable
Organic phosphorus[2]	Not detectable
Lead	0.1 mg/l or less
Chromium (hexavalent)	0.005 mg/l or less
Arsenic	0.05 mg/l or less
Total mercury[3]	0.0005 mg/l or less
Alkyl mercury	Not detectable
PCB	Not detectable

Notes: 1. Maximum values. But with regard to total mercury, standard value is based on the yearly average value.
2. Organic phosphorus includes parathion, methyl parathion, methyl demeton and E.P.N.
3. Standard value of total mercury shall be 0.001 mg/l when river water pollution is known to be caused by natural conditions.

(2) Standards relating to Living Environment

	Item / Purpose of water use	Standard Values[3] pH	Chemical oxygen demand (COD)
A	Fishery, class 1; bathing; conservation of natural environment, and uses listed in B–C[1]	7.8–8.3	2 mg/l or less
B	Fishery, class 2; industrial water and uses listed in C	7.8–8.3	3 mg/l or less
C	Conservation of environment[2]	7.0–8.3	8 mg/l or less

Notes: 1. Conservation of natural environment—Conservation of scenic points and other natural resources.
2. Conservation of environment—Up to the limits at which no unpleasantness is caused to the people in their daily lives including a walk along the shore.
3. Dissolved oxygen (DO), number of coliform groups, and n-hexane extracts are omitted from table.

For all sea areas in Japan some 81 percent achieve the standard. But in Tokyo Bay, however, only 61 percent pass; and in Ise Bay, 47 percent. In the Seto Inland Sea the achievement ratio is 81 percent, while in Osaka Bay it is 67 percent.

Effluent Control

To achieve the environmental quality standards, the government has since 1970 imposed effluent controls on all factories and commercial establishments in Japan, including pulp mills, steel mills, hotels, laundries, sewage treatment plants, and cattle stalls. (These factories and establishments numbered about 280,000 as of 1985.) Before a factory or establishment can be built, the owner must inform the supervising prefectural office of its facilities, its waste water treatment plant, and the quality and quantity of any effluent water to be released. When any of these parameters are to be altered, the owner must inform the prefectural office in advance. That office can approve the plan or order that it be improved, in order to achieve the effluent standards.

The effluent standards consist of two parts. The first, called the general standards, applies to all factories and establishments in Japan. These standards cover 25 pollutants: cadmium, cyanide, pH, COD, and so on. The general standard for COD is set at 160 milligrams per liter of effluent or less.

When many factories and establishments are concentrated in one district, it may be that enforcement of the general standards will fail to bring the area up to the environmental quality standards. In this case the prefectural office may impose the second part of the effluent standards, known as strict standards. These vary between areas and industries; the most strict standard for COD is set at 10 milligrams per liter.

About 180 factories and establishments are cited for violation of one of these two levels of effluent standards each year. But despite these controls, achievement ratios for COD remained at a low level in three semi-enclosed water bodies: Tokyo Bay, Ise Bay, and the Seto Inland Sea.

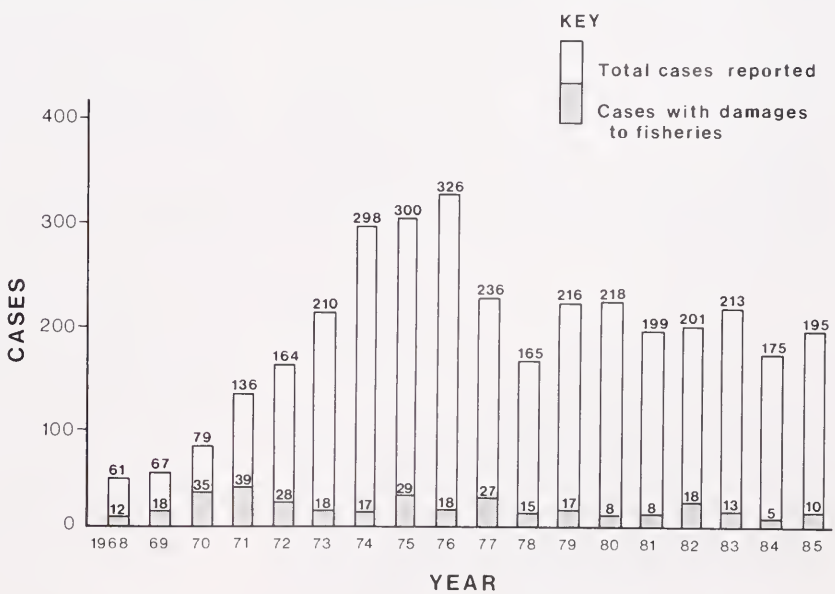


Figure 4. The number of cases of red tides in the Seto Inland Sea.

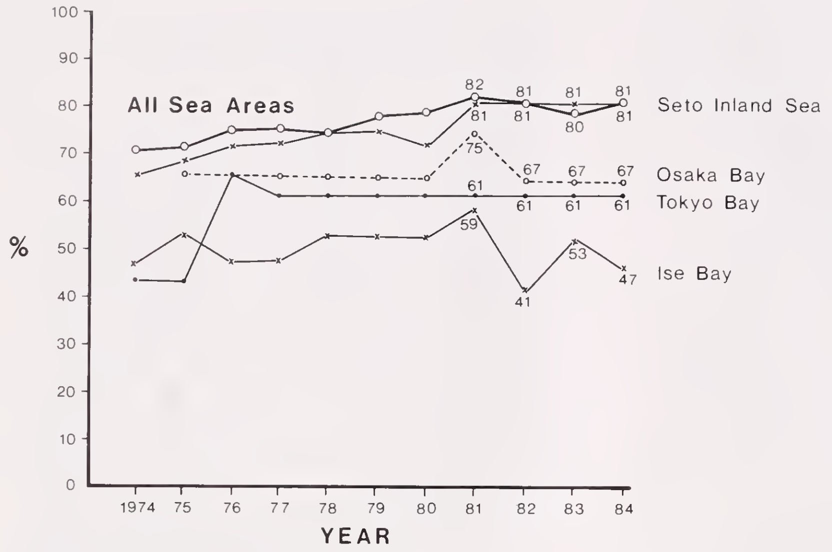


Figure 5. Achievement ratios for the COD environmental quality standard for the principal high-pollution areas in Japan. The achievement ratio is defined as: (number of areas achieving environmental quality standards)/(number of areas to which standards are applied) × 100. The value is expressed as a percentage.

Total Pollutant Load Controls

To address this problem, the government, beginning in 1979, instituted an areawide total pollutant load control for COD. This measure is intended not to restrict the concentration of pollutants in the effluent, but rather the total amount of pollution entering a water body. First, the total pollutant load (the concentration of pollutants multiplied by the volume of water containing those pollutants) for a given area is computed; for example, the total COD from all factories, houses, sewage treatment plants, cattle stalls, cultivated fields, and other sources is totaled up. The government then estimates the total amount of pollutant load which would be expected after certain countermeasures are taken. The prefectural offices then institute these countermeasures, usually with a five-year target date for the achievement.

One of the countermeasures is the application of COD total pollutant load standards to the effluent water from factories and establishments. The pollutant load standard of COD for each factory or establishment is based on the quantity of effluent water generated, and the type of industry involved. Unlike the effluent standard this standard cannot be achieved by diluting the waste water with clean water, for the pollutant load of the waste water does not change with dilution. Pollutants must be removed from the waste water. Each factory must measure and record the value of COD in the quantity of its effluent water. The prefectural offices can request these records at any time.

As to the other countermeasures, the extension of the sewer system, under the jurisdiction of Ministry of Construction, is one of the most important. About 40 percent of the total population in Japan is served by sewers. In other areas, night soil is treated, but gray water is drained without any treatment. (Gray water means the waste water from sources such as the kitchen, laundry room, showers.) The percentage of the population served by sewers is increasing at an annual rate of about 1 percent.

As a result of effluent control, areawide total pollutant load control, and the countermeasures outlined above, Japan no longer faces critical pollution of the sea. But there remain areas where improvement is badly needed. The achievement ratio for environmental quality standards is still low in Tokyo Bay, Ise Bay, and Osaka Bay. In addition, about 200 red tides cases still are reported annually in the Seto Inland Sea. To cope with these problems further efforts must be made.

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Acknowledgment

A number of articles in this issue were translated from Japanese by Shunsuke Obinata, who works for Japanese Language Services, Boston, Massachusetts.

Radioactive Waste Disposal

The Fukushima Daiichi Nuclear Power Station, located along the Pacific Ocean coast. The plant has 6 boiling-water reactors, producing a total of 4.7 gigawatts (giga = billion) of electricity. (Photo courtesy of the Tokyo Electric Power Company)

by Takehiko Ishihara

Japan has a strong commitment to alternative energy sources—largely because it must import nearly 100 percent of its petroleum, 91 percent of its natural gas, and 82 percent of its coal. On top of this, it is estimated that transportation costs add as much as 20 to 30 percent to the price of imported fuels.

As part of the energy mix, the use of nuclear power is increasing. In 1985, 26 percent of Japan's electricity was provided by nuclear power. This is projected to increase to 39 percent in the year 2000, and 48 percent in 2010. Like other nuclear nations, Japan must deal with one of the principal problems associated with nuclear power—disposal of radioactive waste.*

Radioactive waste disposal in Japan has passed through a number of phases. Early on, as did other nations during the 1950s and 60s, some wastes were dumped at sea. Diplomatic and scientific activities in the 1970s explored further dumping in the Pacific. In the early 1980s, all sea dumping ceased because of public protest and international

* See also, Low-Level Radioactivity in the Irish Sea, *Oceanus*, Fall 1986, Vol. 29, No. 3, pp. 16–27.

Nuclear power stations (14 sites, and 32 reactors of 24.5 gigawatts electrical-generating capacity), and other nuclear facilities of Japan.

resolutions. Today, like other countries, Japan has largely shifted to land storage of the waste. But, again, like other nations, Japan continues to explore the feasibility of sea dumping of radioactive waste.

Dumping Versus Storage

Many countries have used the oceans for disposing of their living and industrial wastes, and recently for radioactive wastes. Use of the Pacific Ocean for radioactive waste disposal was initiated by the United States in the 1940s, with the discharge of treated radioactive liquid effluents, and the dumping of packaged radioactive solid wastes.

A decade later, Japan began the utilization of radioisotopes for medical and research purposes, and then introduced nuclear reactors for research and power generation. From these and related activities, some radioactivity-contaminated wastes, liquid and solid, have been generated. They were processed and most of the products were stored on the sites. Some radioisotopes were collected and temporarily stored by the Japan Radioisotope Association (JRIA), and some were processed and stored by the Japan Atomic Energy Research Institute (JAERI) in Tokai.

JRIA dumped some of the packaged radioisotope wastes (330 cubic meters) at a depth of 2,000 to 3,000 meters in the sea off Tokyo Bay from 1955 through 1969. The contained activity was 407 Curies when dumped, and is expected to have decayed out. All other packaged radioisotope wastes are being stored in seven temporary storage facilities located around the country.

At present, 12 research and experimental reactors, and 32 power reactors of 24.5 Gigawatts electrical capacity are being operated. Several fuel recycling facilities are also being operated. They generate more radioactive waste than the radioisotope facilities. All these reactor and fuel cycle wastes are being conditioned and temporarily stored at each site.

As of the end of 1985, Japan is storing 125 thousand cubic meters of conditioned low-level wastes; 7 thousand cubic meters being of radioisotope origin, 85 thousand of power generation origin, 4 thousand of nuclear fuel origin, and 29 thousand from research and development activities.

Early on, it became clear that disposal of the accumulating wastes must be addressed. In 1976, the Japanese Atomic Energy Commission (AEC) framed a fundamental policy on radioactive waste management, and this policy still applies with some modifications. Concerning low- and intermediate-level wastes, it says:

- *Wastes shall be disposed of either into the ground or into the sea depending on their characteristics. Nuclear industries are responsible for processing and disposal, and shall establish a body to implement experimental disposal and to coordinate relevant industrial activities.*

Having this policy, the nuclear industries established the Radioactive Waste Management Center (RWMC) in 1976 to take the first step toward the long-term waste management. At that time Japan began to plan for expanded sea dumping of low-level wastes. The RWMC did various preparatory work, including the design of a dumping ship, development and demonstration of unloading gear for dumping, quality control of waste packages, and

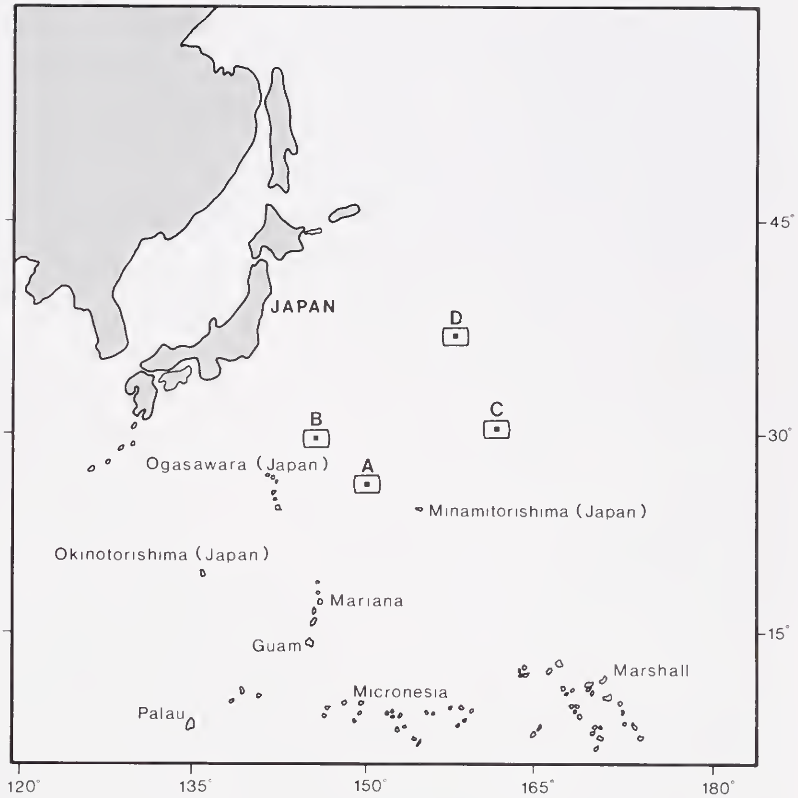

Figure 1. The four sites considered as candidates for radioactive-waste dump sites. Site B (30 degrees North and 147 degrees East) was considered most suitable.

demonstration tests on package integrity. Oceanographic observations and investigations, package integrity tests and environmental safety assessment of the operation were conducted by other governmental marine institutions, JAERI, the Central Research Institute for Electric Power Industry (CRIEPI), the Advisory Committee for radioactive waste management in the Japanese Nuclear Safety Commission (NSC), and others.

At about the same time, the government's Atomic Energy Bureau (AEB) organized a technical study committee on radioactive solid waste management. The committee first defined the necessary criteria for sea dumping sites of low-level wastes. Then, in 1972, the committee selected four candidate sites for disposal (Figure 1). These sites were all located in the Northwest Pacific Basin. Except for one site, they were at a depth of about 6,000 meters, and fell outside the 200-nautical mile Exclusive Economic Zone.

From 1972 to 1974, oceanographic observations and investigations were conducted on the proposed sites and surrounding areas by relevant governmental organizations, the Maritime Safety Agency, the Fisheries Agency, the Meteorological Agency, and the Meteorological Research Institute, with the support of other institutions. Since 1977, further surveys have been conducted by these and other institutions. Candidate site B, at 30 degrees North and 147 degrees East, with depth around 6,200 meters, was concluded to be the most favored and probable dumping site. It is located about 900 kilometers southeast of the mouth of Tokyo Bay. The nearest islands are the Japanese Ogasawara or Bonin Islands, about 550 kilometers away. The nearest foreign island is Maug Island of the Northern Marianas, about 1,100 kilometers to the south.

Along with site selection, there were technical preparations. Because of the site depth, the containers needed to withstand large hydrostatic pressures. Corrosion-resistance was also a problem. Various tests were conducted, including the dumping of simulated packages with attached cables—for recovery after periods of up to 3 years. The Japan Marine Science and Technology Center (JAMSTEC) also developed a deep sea camera system to verify the integrity of the packages during descent and arrival on the seabed. All tests were aimed at meeting the standards established by the International Atomic Energy Agency (IAEA).

The environmental impact assessment was conducted by a working group of the Nuclear Safety Bureau (NSB) of the government in 1976, with results verified by the Advisory Committee for Radioactive Waste Management in the NSC. The experimental dumping at the B site was scheduled to be limited to an amount of 500 Curies packaged in about 5,000 to 10,000 standard drums. A full-scale disposal was planned for a level of 100,000 Curies per year. The analyses conducted included effects on marine organisms, human exposure rates, and worst-case scenarios involving shipwrecks and various accidents. The results were judged to be well within acceptable standards.

Diplomatic preparation was also required. In the fundamental policy on radioactive waste management framed in 1976, the Japanese AEC stressed that efforts to obtain international understanding were imperative, and that sea disposal operations should be carried out in a spirit of international harmony. After reviewing the environmental safety assessment report by the Advisory Committee, the NSC issued a statement that the planned sea disposal would be practiced safely, and the operations would be carried out in 1979 with the proper understanding of all concerned parties. It planned to begin with the experimental dumping of a small amount of wastes, with government-affiliated monitoring and an NSC safety assessment. The process was projected for about two years. When the safety of the experimental disposal had been established, the full-scale disposal would begin.

Regional and International Reactions

Following the news in November, 1979, of Japanese plans for sea dumping of low-level wastes, various inquiries resulted. Protests against the possible dumping operation came from the Northern Mariana Islands of the United Nations Trust Territory, the nearest foreign land to the proposed B site, other areas of the United Nations Trust Territory which were under the United States administration, and Oceanian countries in the South Pacific region.

The Japanese Government dispatched officials of the Science and Technology Agency (STA) in charge of the plan, together with specialists, to explain the content and technical details of the plan to the United States and some European countries in February to March of 1980. Missions were also dispatched to Australia, New Zealand, and other lands in the central and southern Pacific. The Pacific region is very large and has many young countries with rather small populations that have become newly independent. Some of them have suffered from nuclear weapons tests conducted in the region, and are very sensitive to all nuclear-related operations.

International Agreements Halt Dumping

Paralleling the early dumping, and dumping experiments, an international regulatory structure came into existence. In 1972, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters (often referred to as the London Dumping Convention, or LDC) was adopted, and entered into force in 1975. The International Atomic Energy Agency (IAEA) was entrusted as the organization for defining categories of waste and recommending on permit issuance. In 1977, a multilateral consultation and surveillance mechanism was set up to further the objectives of the Convention in the Organization of Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA).

Japan is one of 15 contracting parties to the London Dumping Convention, and is a participant, with Canada and the United States, in the OECD/NEA Consultation and Surveillance Mechanism for Sea Dumping of Radioactive Waste, in the Pacific region. Throughout the procedure, Japan adopted the accepted sea dumping policy for her low-level wastes, and was, and is, prepared to conduct the operation under the IAEA Definition and Recommendations, and OECD/NEA guidelines for radioactive waste dumping.

However, at the 7th consultative meeting of contracting parties to the London Dumping Convention in 1983, a resolution to review sea dumping of low-level wastes scientifically and technically, and to suspend dumping operations for about two years, was adopted. In the 9th consultative meeting, an additional review resolution was adopted, and the dumping suspension is being maintained.

After the dumping suspension resolution in 1983, all countries stopped operations, awaiting an international understanding of low-level waste dumping.

Nuclear-Free Zone

Of particular relevance to the issue, the South Pacific Forum was established in 1971 with members of independent and self-governing countries in the South Pacific. It also included several non-self-governing states in an observer capacity. Since its 1981 meeting, the Forum has adopted repeatedly a resolution opposing nuclear waste dumping and storage in the South Pacific region. On its 16th meeting in 1985, it adopted the South Pacific Nuclear-Free Zone Treaty to ban nuclear weapons testing and storage, and disposal of nuclear materials in a zone that includes a part of the North Pacific. The treaty entered into force in November, 1986.

Other organizations, the South Pacific Commission, and the South Pacific Bureau for Economic Cooperation, together with the United Nations Environmental Programme, organized an intergovernmental conference of 27 island-states and countries including Australia, France, New Zealand, and the United States. An environmental treaty was adopted in November 1986 to prevent, reduce, and control pollution from any source in the region. It prohibits the storage or dumping of radioactive wastes in the treaty area, while it will allow the testing and storage of nuclear devices.

A Changing Direction

In Japan, as in other countries, as the international situation developed, studies of land disposal and storage of low-level wastes were accelerated. A nationwide survey was conducted to locate suitable sites. In parallel, a site survey for reprocessing was pursued.

Nuclear fuel reprocessing is not foreign to Japan. Since 1976, the Power Reactor and Nuclear Fuel Development Corporation (PNC) has operated a reprocessing plant of 0.7 ton per day capacity in Tokai. The processing capacity is not sufficient, however, and about two-thirds of Japanese spent fuels are being sent to French and British reprocessing plants by special transportation vessels. To improve on this situation, the electric power industries and other nuclear industries have established the Japan Nuclear Fuel Services, Inc.

The Tokai reprocessing plant at Tokai-mura, Ibaraki-ken, facing the Pacific Ocean. In the background is the Tokai nuclear power station, and the facilities of the Japan Atomic Energy Research Institute. (Photo courtesy of the Power Reactor and Nuclear Fuel Development Corporation (PNC))

The company is now preparing to construct a commercial reprocessing plant of an 800-ton per year capacity on the Shimokita peninsula, Aomori Prefecture, in the northern part of the Japanese mainland. Low-level waste storage facilities will be established there by the Japan Nuclear Fuel Industries Company, along with an enrichment plant. Low-level wastes of nuclear power stations conditioned and packaged will be transported to the Shimokita facilities, which will have a 200 thousand cubic-meter capacity, after their completion in 1991.

Sea disposal as an option for low-level wastes continues to be studied in cooperation with IAEA, IMO, and OECD/NEA activities, but the execution of a dumping operation appears unfeasible in the near future.

Takehiko Ishihara is a Technical Advisor in the Radioactive Waste Management Center, Minato-ku, Tokyo, Japan.

Japan Opts for French Reprocessing Plant

Japan announced in February of this year that it had selected French technology for the construction of a US$4.6 billion reprocessing plant, to be situated in the far north of Japan's main island, Honshu.

The plant will be based on the same designs as those used for the construction of new reprocessing facilities by the nuclear fuels group Cogema at France's principal reprocessing facility at La Hague, on the country's northern coast. The French technology, according to Science magazine, was chosen after a close competition with British Nuclear Fuels and the West Germany company DKW.

The Use of Ocean Space in Japan

by Kenji Hotta

The interest in developing ocean space in Japan is being rekindled today. In the 1960s, ocean development referred primarily to exploitation of such natural ocean resources as minerals, marine products, and natural sources of energy. Later, however, the definition of resources was expanded to include the concept of space (see *Oceanus*, Vol. 29, No. 3, p. 52).

When one defines space as a component of resources, a new concept of national territory—integrating sea and land—begins to take form. As Japan is a small country with very limited natural

Above, the Gobo Electric Power Station built on an artificial island in 1980. At right, a concept for a port renaissance by the Ministry of Transportation.

resources, ocean space becomes an important factor. It is directly related to the nation's future economic growth and development.

Japan's coastline is 32,000 kilometers long. The nation has a landmass size of 370,000 square meters, 20 percent of which is presently habitable. By comparison, Japan's 200-mile Exclusive Economic Zone (EEZ) covers an area of 4,510,000 square meters—or 12 times larger than the country's land mass. Japan thus possesses an enormous amount of ocean resources.

According to U.S. census data, by the year 2000, 80 percent of the U.S. population will be residing within 50 miles of the coastline (including the Great Lakes). A similar prediction exists for Japan. These trends, if realized, will create a sharply increased demand for urban space in coastal areas.

With these trends in mind, the central government and local authorities in Japan have developed various programs for the use of ocean space. To date, 198 cities have prepared ocean space development plans, and many have ongoing projects in various planning stages.

The objectives of many of these projects are related to regional development; that is, local economic development based on increased domestic demand, coupled with the desire to establish an affluent society. In this sense, these plans differ greatly from those of the 1960s and 1970s, which emphasized the development of heavy industries. The present projects are still in the preliminary feasibility-study stage. Numerous problems must be resolved before their actual implementation.

Ocean Space Utilization Goals

The following ministries and agencies of the central government have ocean space utilization goals, with plans and projects under study:

Offshore Man-Made Islands. The Ministry of Transportation's goal for its offshore man-made island projects is described as follows: "In order for Japan with limited land area to achieve balanced development, it is a vitally important task to push forward ocean space development and utilization based on a long-term perspective, while promoting effective and efficient utilization of the existing land area. For this purpose, research and study efforts are necessary, because Japan's stable development, as well as creation of an affluent and comfortable society, are dependent on expansion of the country's land and space."

The Ministry of Transportation has been engaged in practical case studies as a part of this project. It has been verified through case studies that various industries can be located on offshore man-made islands, allowing them to function as distribution, ocean culture and agriculture, recreation, and ocean development bases. The tranquil ocean area in the back of the man-made islands also can be used for a variety of purposes.

Marine Multi-Zones. The Ministry of Construction's goal is to create "a safe and comfortable" coastal zone to meet the ever increasing demands for marine recreational activities, as well as to plan construction sites for urban facilities. One of the specific objectives of the Ministry of Construction is the technological development of sea-area control structures (large-scale breakwaters). With these structures, the coastal zone can be protected from waves and erosion, subsequently creating a stable, low-energy multi-purpose ocean space.

Sea Ranching (*Farming*). Based on the need for the highly efficient development of mariculture resources in the coastal zone, the Ministry of Agriculture, Forestry, and Fisheries' mission is to secure a stable supply of marine products and to assist regional development efforts by creating new forms of fishery technology. To accomplish these goals, extensive case studies underway include: 1) development of large-scale urban fishery centers, and expansion and stabilization of offshore ocean resources (Marine *Kombinat* Plan); 2) development of the fishery industry sector engaged in hatchery and cultivation activities, and improvement of the living environment of fishing villages (Maritime Village Plan); 3) research and development centered on introducing high technology to the fishery industry (Marine Technology Plan); and 4) preservation of marine cultures and fishing environment (Marine Culture Plan).

Marine Community Polis.* Based on the assumption that the sea can be exploited to achieve new commercial products, and in response to local requirements related to ocean space development of industrial sites and leisure facilities, the Ministry of International Trade and Industry seeks to integrate various types of technology as part of the general effort to make highly efficient use of marine space.

Aqua Marine Plan. The Science and Technology Agency is concerned with defining the technological themes that will be necessary to realize the comprehensive use of ocean space. The specific goals are: 1) promotion and diffusion of marine technology to regional communities to facilitate comprehensive use of ocean space; 2) implementation of policy measures for grasping local needs and developing marine science technology contributing to such needs; and 3) improvement of the ocean development potential of regional communities to strengthen the foundation of ocean development in Japan.

Future Problems

When the notion of space is conceptualized as a resource, its development is fascinating. A bright future appears to await us. However, the implementation of these plans is accompanied by enormous difficulties as well. All plans for use of the marine area, as proposed by the central and local governments, are related to development of the 200-mile Exclusive Economic Zone. As previously outlined, government plans place emphasis on regional development, and, in this sense, are

* Polis: A Greek city-state—in its ideal form a community embodying the organization and fulfillment of man's social relations.

Japan has limited land and must look to the oceans to expand its concept of useable space. (Photo Japan Information Center)

different from those during the boom era of the late 1950s through the early 1970s.

A question often posed is why does Japan have so many new large-scale ocean space projects in the current era—the 1980s—of low-growth and tight finances?

During the boom era, industrial programs were able to progress because of the central government's promotional efforts on behalf of particular development concepts, which regional communities followed.

As the leader of such programs, the central government left little room for local authorities to exercise originality. However, since the beginning of the first oil crisis in 1973, through the present fall of the dollar against the yen, the Japanese development system has undergone change.

The central government now bases its development plans on the existing economic and industrial situation. The government now asks local authorities and private enterprise to draw up practical development plans in a cooperative manner.

From these plans, the central government selects those deemed appropriate, and allocates a budget. The present system differs from the former in that budgets were not directly extended to local governments.

Local governments now have the autonomy to draw up their own plans, reflecting their own originality and individuality. Accordingly, future ocean space utilization and regional development will be characterized by: 1) the central government suggests a comprehensive vision on national land, such as that reflected in the current plans of the ministries and agencies; and 2) each local government will then make efforts to coordinate the plan, maximizing its autonomy and individuality. In other words, the mainstream of future development will be one in which the central government formulates a general response to a need; local governments elaborate on this response in the form of special instructions reflecting regional characteristics; and finally, the central and local governments cooperatively engage in activities to promote the overall development project.

Ocean development is thus moving from the era of the general to one of the specific. In this sense, Japanese ocean development has progressed to a level where specific projects may be implemented. But problems exist. Specific problems at present include:

- *Recognition of actual social needs.*
- *Environmental hazards and restoration measures.*
- *Coordination of space utilization with the fishery industry.*
- *Legal issues concerning sea area utilization.*
- *Establishment of a specific cooperative promotional system by the central government and local authorities.*
- *Establishment of a system to mediate issues between developers and local residents.*
- *Introduction of private capital to development projects.*
- *Establishment of research institutes and development of human resources.*

Environmental Problems

An increase in environmental pollution is a serious problem. It is one of the most significant obstacles to the development of fisheries in the Inland Sea and bay areas, in addition to hindering the development of marine sports and recreation.

Environmental hazards created in the past make it difficult for developers to reach agreement with local communities when attempting to implement new coastal and ocean space utilization projects. Improving and protecting the environment is a major objective of plans aimed at improving the social conditions in ocean areas. Areas suffering from environmental problems must be restored to pristine conditions.

Legal Problems

Under present law, if a private enterprise reclaims part of the sea, use of such land is limited to that concern for its own purpose. That is, resale of the land and a change in its use following reclamation are prohibited by law. Introduction of a free market mechanism into the field of ocean space utilization has been hindered.

These restrictions are imposed because the ocean is recognized as public space. However, based on realistic utilization plans and environmental controls put forth by the central and local governments, there should be some opportunity for private enterprise to engage in free development of ocean space. A legal system supporting such an idea should be studied and reviewed.

Developing Human Resources

A research system that comprehensively supports ocean development must be established along with a sufficient number of qualified personnel to push ocean space utilization in Japan into the 21st century. Basic science should be carried out while simultaneously developing studies specifically geared for practical use. This will require the establishment of special research institutes.

The author is currently teaching in a Department of Oceanic Architecture and Engineering. Oceanic architecture may sound strange, but its definition is generally given as "a study to improve the maritime environment for human activity to create safe and comfortable amenities." In other words, this is a general engineering science. Its goal is to develop space comprised of land and sea through innovative development and conservation technology.

Society will undergo drastic changes in the 21st century, if not before. A new principle of survival is now being questioned in our society, which is being influenced by biotechnology and advanced information technology. When looking back at history, it becomes clear that at any place and at any time there were omens or signs for the future of society. This means that the future is always being created during the present in one form or another. The large-scale use of ocean space is already part of our future.

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Translations of Japanese Journals

A 1981 survey disclosed that 75 percent of Japan's scientific and technical journals are not available in English and other Western languages. Access to Japanese technical literature will be improved under new legislation recently passed by the United States Congress—the Japanese Technical Literature Act of 1986—and by refinements in previously existing programs.

The new legislation calls for translations of selected Japanese journals, an annual report describing significant Japanese technical developments, and a directory of repositories for Japanese technical literature in the United States.

The administrative responsibility for the Act has been assigned to the U.S. Department of Commerce. Since no new monies accompanied the Act, the Secretary has committed funding reprogrammed from within the department. The focus at this time is on producing a compilation of services already in existence for the collection, translation, and dissemination of Japanese technical literature; and on preparing a listing of existing translations. At the present level of funding, a modest number of new translations are envisioned.

These activities are taking place within a program that has been in existence since 1980, and has exchanged technical literature with some 40 organizations in Japan.

Readers desiring additional information should contact:

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Japan's Weather Service and the Sea

by Isao Kubota

Because Japan is surrounded by water, ocean conditions have a particularly significant impact on weather, and thereby on social and economic activities. Prevention of natural disasters, maintenance of safe transportation, and the promotion of industrial prosperity all require accurate weather and climatological information. To provide this information, the Japan Meteorological Agency (JMA) carries out meteorological, terrestrial, hydrological, and oceanographic observations; collects and disseminates these data; and issues forecasts and warnings.

The Marine Department of JMA is responsible for collecting oceanographic and marine meteorological data, and providing forecasts based on these data. The department uses a variety of sources for its data, particularly oceanographic and marine-meteorological reports from ships and coastal stations. Data from foreign vessels collected via the Global Telecommunciation System (GTS) are also used. Domestic sources include vessels of the JMA, the Marine Safety Agency, the Fishery Agency, the Fishery Laboratories, the Defense Agency, and the Education Ministry, as well as merchant ships and fishing vessels.

Above, the eruption of a new island, "Nishino-shima," part of the Ogasawara Islands, on September 14, 1973. In an area known for volcanism and earthquakes, it was the first natural increase of Japanese land area after World War II. (Photo courtesy of Y. Tanaka)

Table 1. JMA research vessels.

Name:	Gross tonnage	Operated by	Cruising area
Keifu-Maru	1796	Marine Department	Seas adjacent to Japan.
Ryofu-Maru	1599	Marine Department	Western North Pacific.
Shumpu-Maru	373	Kobe Marine Observatory	Seto Inland Sea. Southern sea adjacent to Japan.
Seifu-Maru	355	Maizuru Marine Observatory	Japan Sea.
Kofu-Maru	346	Hakodate Marine Observatory	Seas adjacent to Japan. Okhotsk Sea.
Chofu-Maru	700	Nagasaki Marine Observatory	East China Sea.

The parameters analyzed and forecast for the western North Pacific by the Marine Department are sea-surface temperature, subsurface temperature, sea-surface currents, tides, sea ice, and ocean waves. Forecasts cover a variety of time scales, ranging from daily to monthly, and are provided to users by radio facsimile or mail.

Organization of JMA

JMA, which is part of the Ministry of Transport, has five departments: Administration, Forecast, Observation, Seismological and Volcanological, and Marine. The Marine Department consists of three divisions, namely Marine Management, Oceanographic, and Maritime Meteorological divisions. JMA has four marine observatories, in the cities of Hakodate, Kobe, Nagasaki, and Maizuru, as well as a Marine Research Department in the Meteorological Research Institute in Tsukuba Science City. This institute leads the research activities of JMA. The Meteorological College in Kashiwa is in charge of training.

Research Vessels and Merchant Ships

JMA operates six research vessels for oceanographic and marine-meteorological observations (Table 1).

These vessels have surveyed routes in the seas adjacent to Japan in all four seasons, and have surveyed the western North Pacific in both winter and summer. Except for *Keifu-maru*, the vessels are used in research on large-scale and long-term fluctuations in oceanographic conditions, and in monitoring marine pollution. The *Keifu-maru* conducts research on typhoons, mid-latitude cyclones, and *Bai-u* (summer monsoon) fronts. Since 1977, JMA also has monitored deep ocean currents using the *Ryofu-maru*.

In carrying out their cruises, the six vessels rely on such oceanographic tools as hydrographic casts, bathythermographs, and Geomagnetic Electric Kinetographs (GEKs). The bathythermograph data are immediately reported as a "BATHY" report to JMA via coastal radio stations or the Geostationary Meteorological Satellite (GMS) operated by the agency. Surface meteorological synoptic observations are made every three hours and reported as a "SHIP" report to JMA. These BATHY and SHIP reports also are sent to the foreign meteorological services through GTS.

In addition, *Keifu-maru* and *Chofu-maru* have observation systems capable of detailed atmospheric measurements, and *Chofu-maru* features an acoustic doppler current meter instead of a GEK. Data from all six vessels are published in *The Results of Marine Meteorological and Oceanographical Observations*, or, *Prompt Report of Observation for Monitoring Background Marine Pollution* on an annual basis. JMA also collects surface observations from merchant ships. The data are utilized in weather and wave forecasts and warnings, as well as sea-surface temperature (SST) analysis, and also are sent to foreign meteorological services through GTS.

Marine-meteorological statistics for the western North Pacific are summarized in the *Marine Climatological Tables of the North Pacific Ocean* and the *Marine Climatological Summary* annually.

Moored Buoys

Four ocean data buoys operated by JMA automatically measure 13 meteorological and oceanographic parameters at three-hour intervals. JMA's Meteorological Satellite Center collects these data via the GMS and reports them to the world via GTS every three hours as a "SHIP" and "DRIBU" report. Included are measurements of wind direction, wind speed, air temperature, dew point temperature, atmospheric pressure, water temperature at depths of 2, 50, and 100 meters, significant wave height, wave frequency, solar radiation, and the orientation and inclination of the buoy. The data from JMA's buoys are compiled in *Data From Ocean Data Buoy Stations* on an annual basis.

Coastal Stations

JMA operates 61 tidal stations, 23 coastal sites to measure the SST, and 11 wave observation stations, which use an ultrasonic wave gauge settled on the seabed at a depth of 50 meters. The SST data from the sites are issued in *The Results of Marine Meteorological and Oceanographical Observations*. Statistical data from the wave observations are published as *The Results of Sea Wave Observations* on an annual basis. Data from the 60 tidal stations, including the sites belonging to other organizations, are transmitted to the nearest meteorological stations every 1.3 seconds to assure quick announcement of storm surges, abnormal tides, or tsunamis. The records are compiled in *Tidal Observations* on an annual basis and in *Prompt Tidal Observations* on a monthly basis.

Data Analysis

Using data from these various sources, JMA analyzes sea-surface temperature, subsurface temperature, surface currents, tides, sea ice, and waves. For the

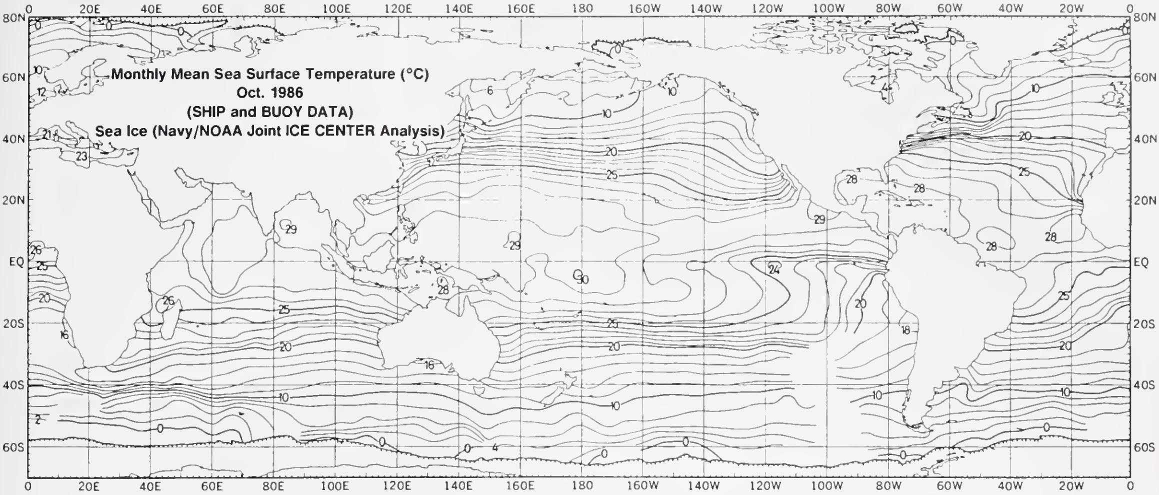

Figure 1. Monthly sea-surface temperature as issued in The 10-Day Marine Report.

SST, a computerized technique is employed to derive a 10-day mean for points throughout the western North Pacific. The points form a grid defined by 1 degree of longitude and 1 degree of latitude. For points where no data is available, an estimated value is derived from nearby data points. Adjustments are made based on SST measurements from satellites and the subsurface thermal structure. Using the same procedure, but on a 2-degree grid, SST patterns over the entire Pacific are derived every 10 days. Finally, the SST of the whole globe is analyzed on a 2-degree grid each month (Figure 1).

Since March 1986, JMA has forecast the 10-day mean SST on a trial basis for the western North Pacific. The forecast is based on the estimated heat exchange between ocean and atmosphere. The amount of the heat exchange is semi-empirically obtained using the previous 10-day mean SST, climatological data, and the depth of surface mixed layer. Forecasting methods are now being improved intensively. In particular, JMA is working to introduce predicted meteorological conditions obtained from extended numerical weather forecasting.

The analysis of temperature at a depth of 100 meters is carried out subjectively by experts based on the BATHY reports and other domestic data every 10 days for the western North Pacific (Figure 2). A similar analysis of temperature is made on a monthly basis for the whole North Pacific, including the equatorial regions. Furthermore, the depth of the surface mixed layer also is analyzed.

Sea-surface currents in waters adjacent to Japan are analyzed every 10 days (Figure 3). The current data are derived from research vessel measurements and domestic data exchanges. The currents are plotted on a chart that shows the location of the major currents—such as the Kuroshio and the Oyashio.

Sea-level data and tidal harmonic constants are obtained every year at 98 tidal stations run by JMA (61), the Hydrographic Department (9), the Geographical Surveys Institute (6), and others (22). Astronomical tides for all these stations are calculated and published in *Tide Tables* every year.

In winter, the Okhotsk Sea, the northern part of the Japan Sea, and the Bohi are covered with sea ice. Information concerning such ice is essential for shipping, fisheries, and other industries. JMA has collected data on sea ice from ships; airplanes; the GMS meteorological satellite, as well as those satellites operated by the U.S. National Oceanic and Atmospheric Administration; sea ice radar; and coastal stations. The data are analyzed twice a week from December through May, and the results are broadcast by radio facsimile from JMA and issued in *The Results of Sea Ice Observations* annually.

JMA began daily ocean wave analysis and broadcast for the western North Pacific (15N to 60N,110E to 180E) in January 1972. Since March 1977 computerized forecasts of ocean waves have been carried out using a numerical wave prediction model. Analyzed charts of ocean waves are compiled in *Ocean Wave Charts*, and hindcasted results of the wave model in the coastal area of Japan and statistical analyses are published in *The Wave Data Calculated by Numerical Method* annually.

The Specialized Oceanographic Center

JMA also runs a Specialized Oceanographic Center, which produces a variety of operational oceanographic products, including analyses and forecasts of SST, anomalies from the long-term normals, analyses of sea-surface currents, and analyses of subsurface temperatures. These are broadcast in radio facsimile from JMA, and are printed and sent by mail to domestic and foreign users every 10 days, in *The 10-Day Marine Report*. Examples of the data included are shown in Figures 1, 2, and 3.

International Cooperation

In addition to its domestic programs, JMA seeks to promote international cooperation in a variety of

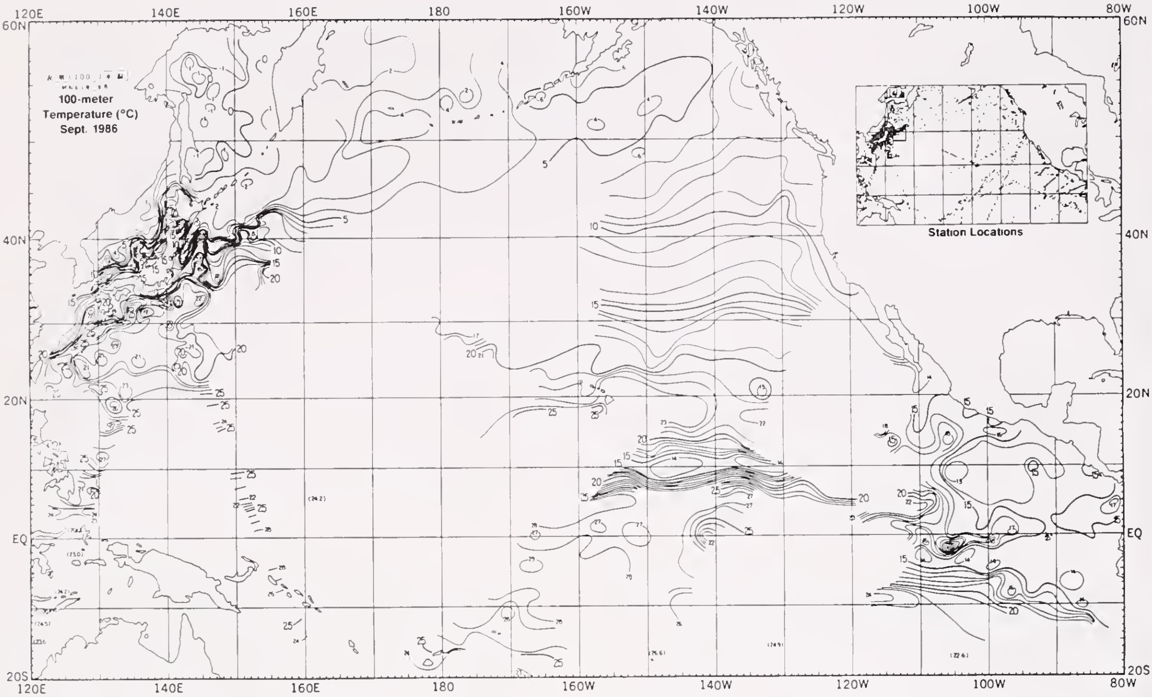

Figure 2. Monthly mean temperatures at a depth of 100 meters in the Pacific.

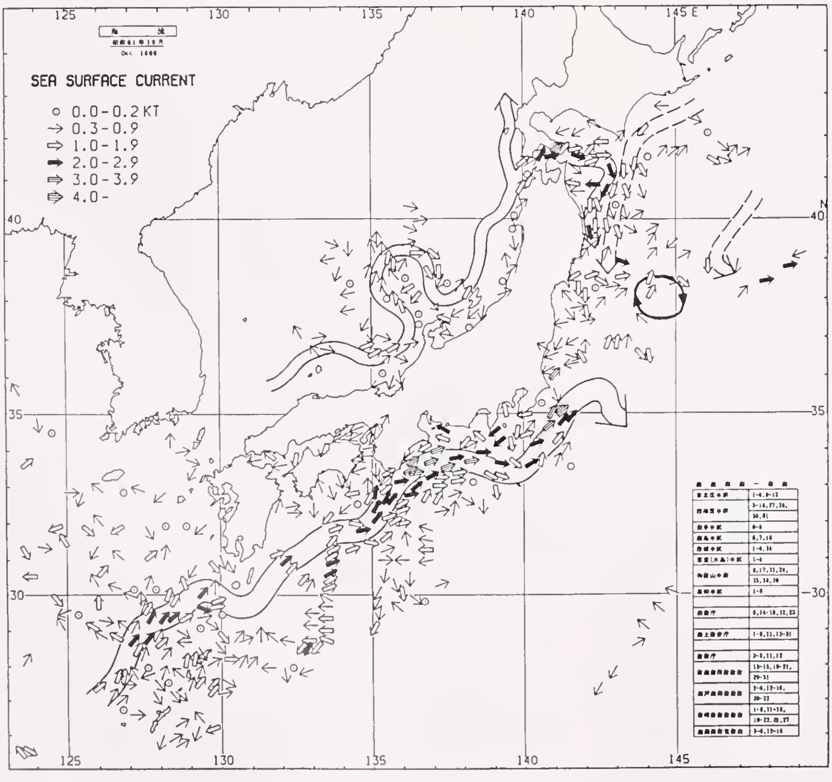

Figure 3. Sea-surface currents in waters adjacent to Japan. Note the location of the Kuroshio Current running along the nation's south shores.

fields. One such area is the International Global Ocean Service System of the World Meteorological Organization and the Intergovernmental Oceanographic Commission. The SOC participates fully in this effort.

Japan also participates in a cooperative research program with 16 other Western Pacific nations. One or two scientists from these nations study oceanographic conditions from the *Ryofu-maru* each year. In addition, Japan and China began a cooperative study on the Kuroshio Current last year. This research is scheduled for completion in 1992.

A Crucial Link

These various analytic and forecasting activities are crucial to a wide variety of economic activities in and around Japan. Subsurface temperature and SST information are used to find oceanographic fronts, which in turn helps locate productive fishing areas. In addition, SST information is used in local weather forecasts and for long-range predictions.

Information on currents is crucial for shipping. When combined with temperature information, the current data will be useful for such global efforts as the World Climate Research Program now being implemented by the World Meteorological Organization. Together with data on ocean waves, current information is helpful for calculating sediment transport.

Sea ice and ocean waves are of vital importance not only for shipping, but also for the design of offshore and coastal structures. Altogether, the information gathered and analyzed by the JMA is crucial to the health of Japan's economy.

The Western Pacific and El Niño

One of the strongest phenomena affecting both the ocean and the atmosphere over the course of a few years is the El Niño event and the related Southern Oscillation, together referred to by the acronym ENSO. The effects of ENSO most easily noticed by the public include torrential rains and storms in areas that normally experience mild weather, and droughts in many normally rainy areas. But oceanographers and meteorologists tend to look more to changes in atmospheric and oceanic conditions in the Pacific.

During an El Niño period, sea-surface temperatures (SST) in the central and eastern tropical Pacific are higher than normal. Air pressure over the eastern South Pacific is lower than normal, while over the western tropical Pacific it is higher than normal. As a result of these pressure changes, the easterly winds typical over the Central Pacific weaken.

But although the characteristics of an ENSO event in the eastern Pacific are well known, in the west, sufficient oceanographic observations are not yet available to adequately characterize the effects of an El Niño.

Japan's Role

The Japan Meteorological Agency (JMA) has carried out oceanographic surveys along the 137th East meridian since 1967. Analysis of the results of these profiles through time has exposed the relation of oceanographic conditions to ENSO.

Briefly, during an El Niño, the sea-surface temperature of the western equatorial Pacific tends to be lower than normal. Hadley circulation (in which air rises at the equator, spreads north and south, and then sinks again at about 30 degrees North and South) weakens over the western Pacific during the boreal summer of an El Niño year. At the same time, sea and air temperatures in the Far East tend to be lower than normal.

Oceanographic Analyses

The JMA started analyzing SST over the whole Pacific in March 1986. Since April 1986, the JMA has analyzed temperatures at a depth of 100 meters in the Pacific, as well as global SST. Historical analyses of SST over the western equatorial Pacific are not available before 1978. Such analyses would be useful in understanding previous El Niño events.

The research vessel *Ryofu-maru* has been used for oceanographic observations along 137 degrees East from 34 degrees North to 1 degree South each January since 1967, and each July since 1972. Physical, chemical, and biological observations are made from surface to near bottom every 5 degrees of latitude, and to 1,250 meters depth every 1 degree in latitude. Marine-meteorological observations at the surface are made every 3 hours.

The temperature profile along 137 degrees East in January for 7 previous years is shown in Figure 1. The El Niño index, which is the SST standardized departure from normal in the area near the west coast of America is shown for January on the left side of the figure. The 25 degree Celsius contour represents the approximate top of the thermocline. Comparing the El Niño index with the depth of the thermocline and the temperature of the surface mixed layer in the equatorial area, one finds that when the El Niño index is positive, the surface mixed layer is thinner and colder.

This relation may be clearer in Figure 2, which

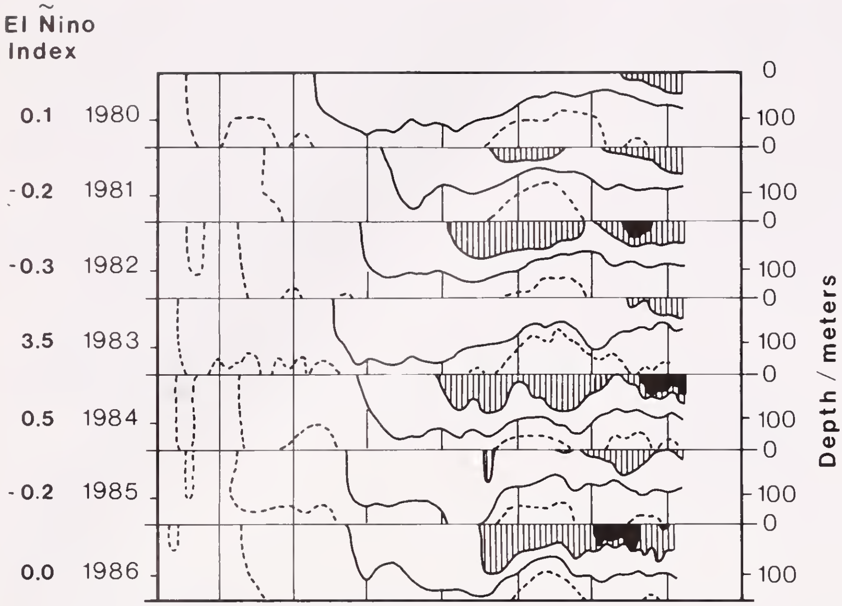

Figure 1. Year-to-year variation of the surface layer of the ocean along 137 degrees East longitude for the years 1980 to 1986. The mixed surface layer is defined here as the layer warmer than 25° Celsius. The January El Niño index, indicating the SST anomaly along the west coast of South America, is shown along the left of the figure.

shows the monthly El Niño index and the Southern Oscillation index, and SST departures from the mean at 0 to 15 degrees North along 137 degrees East, and departures from the mean at 100 meters depth at 7 degrees North and 137 degrees East, from 1972 to 1986. Year-to-year variations of both surface and the 100-meter temperature have a negative correlation with the El Niño index. In strong El Niño years, such as 1972, 1976, and 1982/83, water temperatures at both the surface and the 100-meter-depth are low. In years such as 1973, when SSTs in the central and eastern tropical Pacific are lower than normal and the easterly winds are stonger than usual—a condition that can be referred to as La Niña—water temperatures tend to be high.

During the summers of El Niño years, SSTs in the western North Pacific (above 30 degrees North), the Japan Sea, and the East China Sea, tend to be lower than normal, and the tendency is particularly strong east of Japan. Cold gyres in the East China Sea are stronger and colder during the summers of El Niño years.

Terrestrial Effects

The signature of El Niño is not limited to the oceans in the Far East. Many papers in the Republic of China report that the northeast district of China tends to have cool summers when the equatorial East Pacific SST is abnormally high.

In Japan during El Niño years, a cool summer or autumn is likely, with September particularly likely to be affected. Indeed, a significant positive correlation exists between surface air temperature in Tokyo and the temperature of the surface mixed layer in equatorial regions along the 137th East meridian.

The 1982/83 El Niño

In 1982 and 1983, the greatest ENSO phenomena of this century occurred, while 1984 showed typical La Niña characteristics. During these years, intensive meteorological and oceanographic observations were made over the western equatorial Pacific. Therefore, comparison of conditions over the western equatorial Pacific is more effective for these

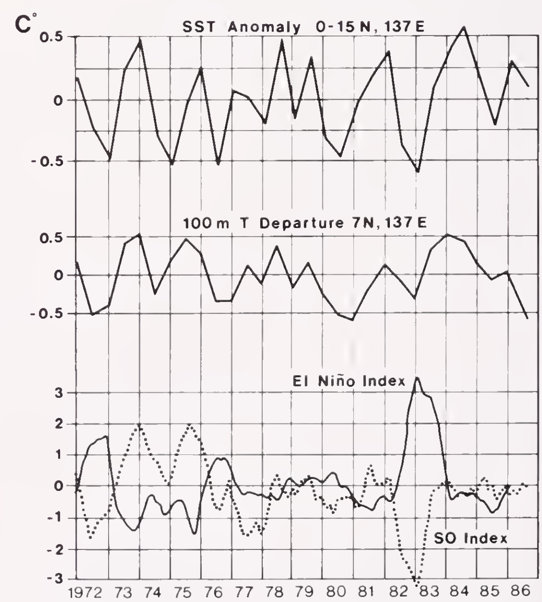

Figure 2. At 137 degrees East longitude, differences in both sea-surface temperature (top) and temperature at a depth of 100 meters (middle) from their respective averages are correlated with the El Niño index and the Southern Oscillation index (bottom). During strong El Niño years, water temperatures in the western Pacific are lower than average.

more recent years than comparisons between previous years.

The strong contrast between the 1982/83 and the 1984 conditions showed up in the departure from normal temperatures at the thermocline in the low latitudes. The amount of the SST anomaly was as large as minus 5 degrees Celsius in 1982/83, and plus 5 degrees Celsius in 1984. In the whole mixed layer south of 15 degrees North, it was cooler than normal in 1982/83 and warmer than normal in 1984. That is, in the western equatorial Pacific, SST was much colder, and convective activity was much weaker during the El Niño of 1982/83, and SST was much warmer and convective activity was much stronger in 1984 (Figure 3).

In summary, during an El Niño event, the equatorial West Pacific has a colder surface mixed layer, less active convection over the sea, and a weaker Hadley circulation than normal. In summer, the Far East is covered by the northern subtropical high, where the northern subsident branch of the Hadley circulation takes place. The weaker Hadley circulation reduces the strength of this high pressure system, and the surface of the Far East becomes colder than normal.

Intensified Oceanographic Observations Essential

ENSO is a global phenomena. To understand and forecast climatic change, ENSO must be investigated and understood. In what way is ENSO behaving over the western equatorial Pacific, the western South Pacific, and the Indian Ocean? What oscillation in the circulation of the subsurface layer of the ocean takes place in relation to ENSO? Why is it only in summer that we find a relationship between equatorial water temperature, climate over the Far East, and Hadley circulation? What is the response of southern Hadley circulation to El Niño? These problems should be urgently investigated. For that purpose, continuing oceanographic observations and prompt reporting systems are required.

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Selected References

Hu, D-X. 1986. Signature of El Niño in the East China Sea. *IOC Technical Series* 3(31): 43–50.

Kurihara, K. 1985. Relationship between the surface air temperature in Japan and seawater temperature in the western tropical Pacific during summer. *Tenki* 32: 407–417. (In Japanese).

Kurihara, K. and M. Kawahara. 1986. Extremes of East Asian weather during the post ENSO years of 1983/4—severe cold winter and hot dry summer. *Journal of the Meteorological Society of Japan* 64: 493–503.

Philander, S. G. H. 1985. El Niño and La Niña. *Journal of the Atmospheric Science* 42: 2652–2662.

Rasmusson, E. M., and J. M. Wallace. 1983. Meteorological aspects of El Niño/Southern Oscillation. *Science* 222: 1195–1202.

Rasmusson, E. M. 1984. El Niño: The ocean/atmosphere connection. *Oceanus* 27: 3–12.

Wyrtki, K. 1982. The southern oscillation, ocean-atmosphere interaction, and El Niño. *Marine Technology Society Journal* 16: 3–10.

Xu, Z-y., R-h. Bai, S-l. Wei. 1982. Relation of cool summer of Hei long jiang in North East District of China to sea surface temperature anomalies of eastern equatorial Pacific and the long range forecast. *Grosswetter* 21: 1–9. (In Japanese).

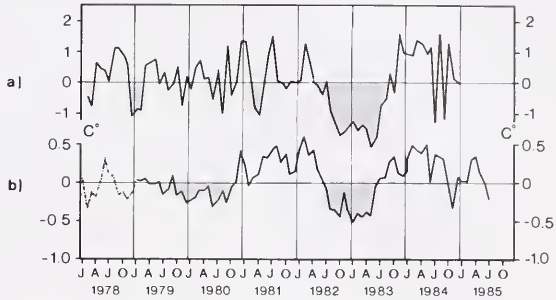

Figure 3. Time series of monthly mean high-cloud amount anomaly (a) and monthly mean SST anomaly (b) for the western North Pacific. The 1982/83 El Niño event, the greatest in this century, is seen clearly in these data.

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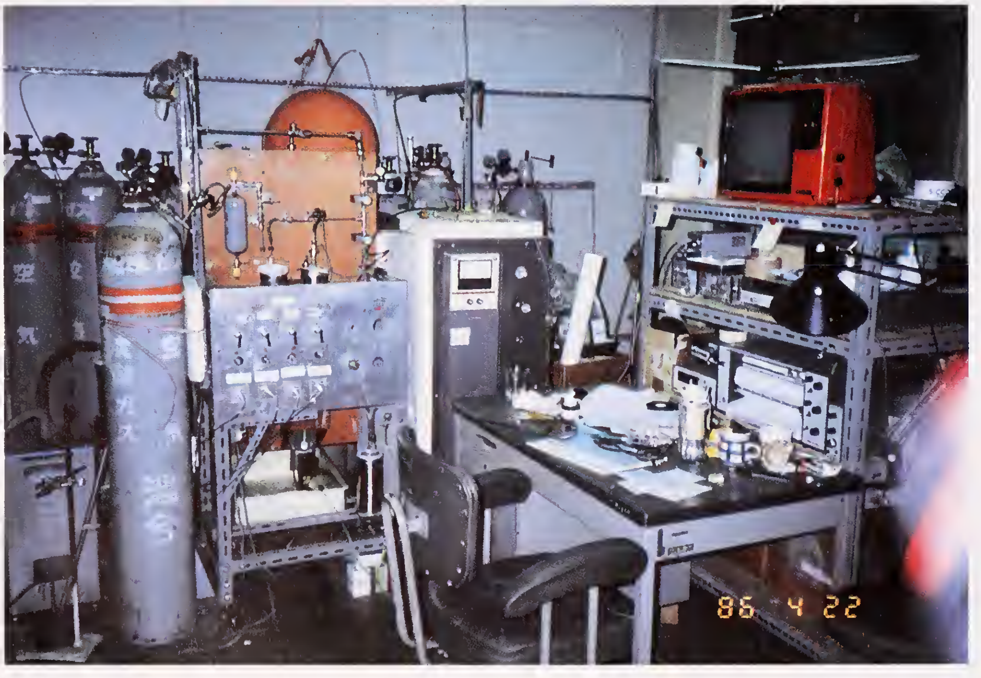
The Atmospheric Carbon Dioxide Problem

by Yasushi Kitano, and Masayuki Tanaka



Apparatus for continuous measurement of atmospheric CO_2 concentration.

Since the 1850s, human activities have increased the carbon dioxide (CO_2) concentration of the terrestrial atmosphere from about 280 parts per million (ppm) to slightly more than 345 ppm. The recent average rate of CO_2 increase is 1.3 ppm per year, with a distinct seasonal variation (high in the spring and low in the fall). At this rate the CO_2 concentration will reach almost twice the present concentration within the next 100 years. At that time the average air temperature will have risen 3 degrees Celsius (± 1.5 degrees). This will cause a serious change in the Earth's climate.*

Since 1974 the authors, along with other colleagues, have been engaged in research on the atmospheric CO_2 problem. This work is sponsored by the Ministry of Education, Culture, and Sciences in Japan as a special research project on environmental sciences, and is carried out, in part, at the Water Research Institute of Nagoya University, Nagoya; and at the Upper Atmosphere Research Laboratory of Tohoku University, Sendai. Recently the Ministry announced further support of these CO_2 studies as a part of the scientific activities of the world climate research program.

The motivation for climate research in Japan is twofold: 1) The dining table of the Japanese people depends on imported foods from the world's bread baskets such as the United States/Canada and Australia/New Zealand. Ensuring a stable supply of food is one of the most important factors in the

* See also the special issue of *Oceanus*, "Changing Climate and the Oceans," Winter 1986/87, Volume 29, Number 4.

welfare of our nation. Therefore CO_2-induced climate change and its influence on the world food situation is of more than academic interest; and 2) We also attach great importance to the potential impact of sea level rise, because most of the population and industry of Japan is concentrated in coastal lowlands.

The Central Question

There is little doubt that man's activities—a "source"—have been responsible for releasing additional CO_2 to the atmosphere. There also is little doubt that, while a portion of the increase is retained by the atmosphere, another portion is transferred elsewhere—to a "sink." While the oceans act as a sink, their exact role is unclear, as is the percentage of CO_2 they account for. Scientists have speculated on the role of this and other sinks, but to date, all CO_2 transferred from the atmosphere is unaccounted for, leading to the nagging but important question of "the missing sink."

The CO_2 increase in the atmosphere has been attributed to the burning of fossil fuel and also to the worldwide destruction of forest (deforestation). The amount of CO_2 supplied to the atmosphere by the burning of fossil fuel is estimated to be 18 billion tons of CO_2 per year. Forest ecologists in Japan estimate the amount of CO_2 discharged globally to the atmosphere from the forests to be 7 billion tons of CO_2 per year, although geophysicists comment that the recent CO_2 supply from forests is less significant than previously thought. Quantitatively, the sources and sinks of atmospheric CO_2 are not very well established.

The ocean is considered to be the most significant sink of atmospheric CO_2. Total seawater contains an amount of CO_2 nearly 60 times (130 trillion tons of CO_2) greater than that contained in the total atmosphere (2.4 trillion tons of CO_2). Thus, it was thought that only 1/60 of the CO_2 amount reaching the atmosphere might remain there, with the remainder being absorbed into seawater.

However, it has been observed recently that about half of the CO_2 released by the consumption of fossil fuel remains in the atmosphere, increasing the atmospheric CO_2 concentration at the rate of 1.3 ppm per year. Geoscientists and environmental scientists in Japan are working to clarify the sources and sinks of atmospheric CO_2, and to estimate the geochemical balance of CO_2 under the conditions before and after the Industrial Revolution.

Lessons from Neighboring Planets

Inspecting the atmospheres of the neighboring planets on both sides—Venus and Mars—helps in understanding our own. The chemical composition of the atmospheres of Earth and its neighbors is shown in Figure 1. It is apparent that the chemical compositions of the atmospheres of Venus and Mars are similar, but that of the Earth is completely different.

Here again, the question of atmospheric sources and sinks comes into play. Figure 2 shows the distribution of carbon in the present Earth's surface, including atmosphere, hydrosphere, biosphere, and sedimentary material, presented by W. W. Rubey and A. Poldervaart. Sedimentary carbonate and organic carbon in soils are the most significant reservoirs of CO_2 on the Earth's surface. If all of the carbon existing on the Earth's surface was released into the atmosphere, and all of the oxygen in the present atmosphere due to the biological activity was removed, the chemical composition of the hypothetical primitive atmosphere of the Earth becomes similar to those of Venus and Mars.

The difference in the chemical composition of the atmosphere among Venus, Mars, and the Earth is due to the existence of large carbon reservoirs on the Earth; both the carbonate sediment and the organic carbon formed in the biological system.

New Measuring System

To understand the distribution and migration of CO_2

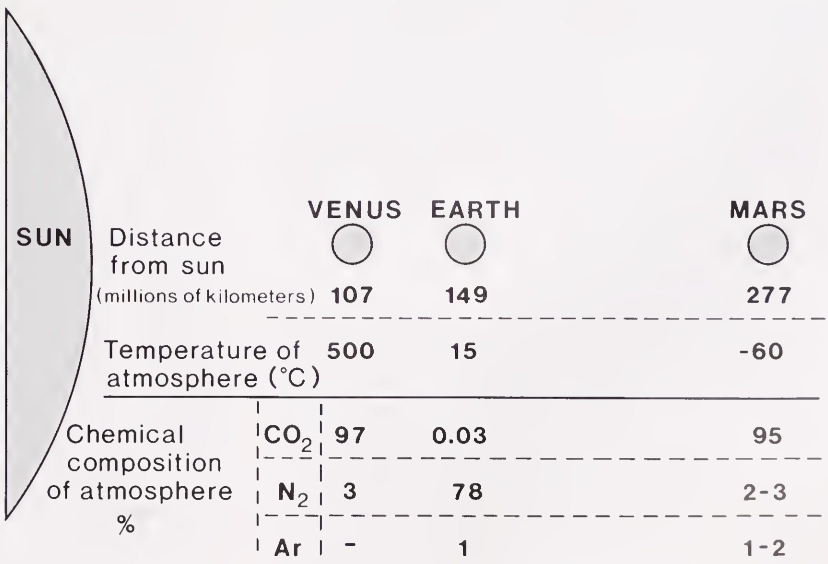


Figure 1. Chemical composition of the atmospheres of Venus, Earth, and Mars.

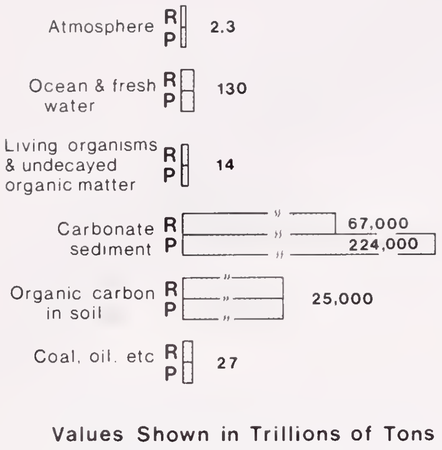


Figure 2. Inventory of carbon (as CO_2) in the atmosphere, hydrosphere, biosphere, and sedimentary rock. Letter symbols are: R, after W. W. Rubey; and P, after A. Poldervaart.

on the Earth's surface, precise measurements of CO_2 concentration in air and seawater should be made continuously. A new apparatus for continuous measurement of atmospheric CO_2 concentration was developed at Tohoku University, Sendai, using a non-dispersive infrared CO_2 analyzer with a precision of better than ±0.01 ppm. Standard gases for the CO_2 analysis were prepared by the gravimetric method using an extremely precise balance; their concentrations were determined with absolute accuracies of ±0.1 ppm.

By mixing a small amount of air in a closed circuit with a large amount of seawater, the dissolution equilibrium, with respect to CO_2, is attained quickly between air and seawater. Thus, the partial pressure of CO_2 in air in the closed circuit is regarded as the same in seawater pumped up continuously from the sea surface into an equilibrator. Two liters of air are adequate to equilibrate in the closed circuit, which consists of a small pump, an electric dehumidifier, a chemical desiccator, and a non-dispersive infrared gas analyzer. Using this method, the partial pressure of CO_2 in seawater was determined with an accuracy of ±0.3 ppm in the laboratory of the Meteorological Research Institute, Tsukuba, and with an accuracy of ±0.4 to ±0.5 ppm during shipboard analysis.

Tropospheric* CO_2 Over Japan

Measurements of CO_2 concentration over Japan have been taken from aircraft since January, 1979. The average seasonal variation of atmospheric CO_2 showed maximum concentrations in early April and early May, and minimum concentrations in mid-August and mid-September for the lower-most and upper-most layers of the troposphere, respectively. The peak-to-peak amplitudes of the seasonal variation were 14.5, 9.0, and 7.8 ppm for the lower, middle, and upper troposphere, respectively. The average rate of annual increase in the CO_2 concentration for the last 6 years was about 1.3 ppm per year. The CO_2 concentration decreased gradually with height, and the concentration difference between the lowest and the highest layers of the troposphere was about 2 ppm, which indicates the CO_2 source is on the ground.

The precise measurements of atmospheric CO_2 at various stations in Japan also have been carried out continuously; in the suburbs of Sendai (December 1978 to June 1981), on the summit (3,776 meters) of Mt. Fuji (July to October 1981), at Tsukuba (July 1981 to October 1983), and at many other stations.

The accuracy of the aircraft measurements was corroborated by those from ground stations. An average rate of CO_2 increase of 1.6 ppm per year, and a fairly regular seasonal trend obtained from the measurement in the suburbs of Sendai, were very close to those of aircraft measurements in the lower troposphere for the same period. The CO_2 concentrations on Mt. Fuji, were very close to those in the middle troposphere over Japan.

Antarctic Measurements

As part of our efforts to obtain data on a global scale, we also have taken measurements since January of 1983 at Syowa Station (69.0 degrees South and 39.6 degrees East) on Antarctica.

Since the station is isolated from vegetated lands and industrial regions, it was expected that not only the mean rate of annual increase in the CO_2 concentration, but also its small year-to-year fluctuation could be precisely detected. The continuous measurements during the period from January 1983 to the present show that: a) a regular diurnal variation was not observed, b) a seasonal variation was observed with the minimum concentration in mid-April, and the maximum concentration in mid-October, and the peak-to-peak amplitude was about 1.2 ppm, c) annual mean concentrations were 341.2 and 342.6 ppm for the years 1983 and 1984, respectively, and d) irregular variations were sometimes observed with extremely small amplitudes of 0.2 ppm. These irregular variations were attributed to the air mixing associated with synoptic scale weather disturbances.

Pacific Measurements

Our sampling program also has utilized ships-of-opportunity. Systematic collection of air samples on the Pacific Ocean was begun in March, 1982, by a container ship sailing between Japan and Australia. A current picture of seasonal and meridional variations of lower tropospheric CO_2 concentration is shown in Figure 3. The data indicate that: a) the annual mean CO_2 concentration was high in the mid-Northern Hemisphere, decreased gradually southward to low values in the mid-Southern Hemisphere, and increased again slightly in the Antarctic region. The concentration difference between the mid-Northern Hemisphere and the Antarctic region was about 3 ppm, b) the amplitude of the seasonal variation was

* The troposphere is the lowest layer of the Earth's atmosphere, extending from the surface out 7 to 10 miles.

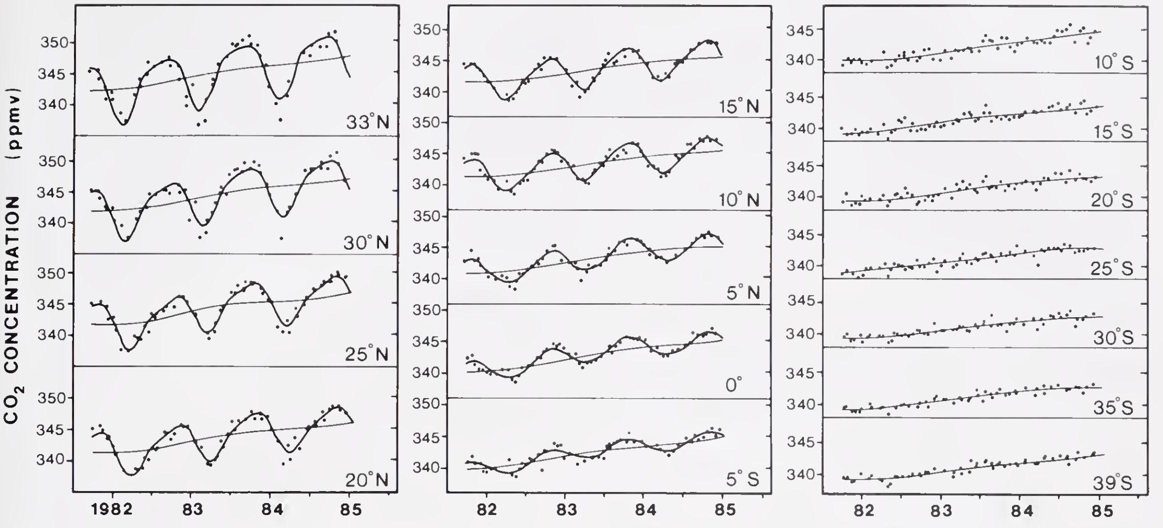


Figure 3. a) CO_2 concentrations between temperate latitudes 33 degrees North and 20 degrees North, over the Pacific Ocean. Circles denote single measured values, thick lines the best fit to the data, and thin lines the seasonally adjusted values; b) for tropical latitudes between 15 degrees North and 5 degrees South; and c) for southern latitudes between 10 degrees South and 39 degrees South.

about 15 ppm in high- and mid-latitudes of the Northern Hemisphere and decreased southward to about 1 ppm in the Southern Hemisphere, c) the maximum and minimum concentrations of the seasonal variation in the mid-latitudes of the Northern Hemisphere appeared in early April, and mid-August, respectively. Their appearance was delayed gradually southward and northward from that latitude, and d) the annual mean rates of CO_2 increase were 1.3 and 1.7 ppm per year for 1982–1983, and 1983–1984, respectively, in all latitudes covered by this measurement. Such a large fluctuation of the rate of CO_2 increase was mainly attributed to the occurrence of the El Niño event in 1982/83 (see also page 75).

Ocean Flux

The flux, or flow, of CO_2 across the atmosphere/ocean boundary is an important component in understanding the global CO_2 system. The rate and direction of flow are determined largely by the partial pressure* of the gas.

The partial pressures of CO_2 in air and in surface seawater were determined by Miyake and others in the North and South Pacific in 1974. The horizontal distribution of the difference in CO_2 partial pressure between air and surface seawater is shown in Figure 4 (a CO_2 partial-pressure diagram for the Atlantic Ocean is given in *Oceanus*, Vol. 29, No. 3, p. 24).

When the partial-pressure difference is positive, CO_2 is released from ocean to atmosphere and when negative, CO_2 is absorbed from atmosphere to ocean. A large excess in CO_2 was observed in the surface waters in the area off South America and in the equatorial region. On the other hand, a deficit was observed in the surface waters of most parts of the North Pacific. According to the calculation of the exchange rate of CO_2 between atmosphere and ocean in 1974, the rate of the release of CO_2 from the Pacific Ocean to the atmosphere was much higher than the rate of the absorption from the atmosphere to the ocean. Miyake and his colleagues therefore concluded that the Pacific Ocean is a source, rather than a sink, of CO_2 for the atmosphere.

Following on this earlier work, additional partial pressure values were obtained by Sugimura and others for the western North Pacific during the winter season (January to February) from 1981 to 1985. The values in the surface seawaters were again found to vary with geographical location; they were low in the mid-latitudes, and high in the equatorial region. Surface seawater in the temperate region showed a seasonal variation in the partial pressure of CO_2, which was low in winter, and high in summer.

Similar measurements were made in the Southern Ocean (south of Australia) during the period from November, 1983 to February, 1984. In this region, the value of the partial pressure of CO_2 in the air was almost constant (about 342 ppm) throughout the measurements, whereas that in the surface seawater varied considerably from 300 to 356 ppm. In general, the partial pressure in surface seawater tended to increase from north to south, and exceeded the atmospheric partial pressure in high latitudes. Thus, Sugimura and his colleagues concluded that the Antarctic Ocean acts as a net source of CO_2—at least in the summer season in the region south of Australia.

The Missing Sink

A number of problems remain. Despite measurements taken around the globe by ourselves and other researchers, it remains very difficult to evaluate quantitatively the net exchange rate of CO_2 between the global atmosphere and ocean.

* The partial pressure of a gas is the pressure that it would exert against the sides of a theoretical container.

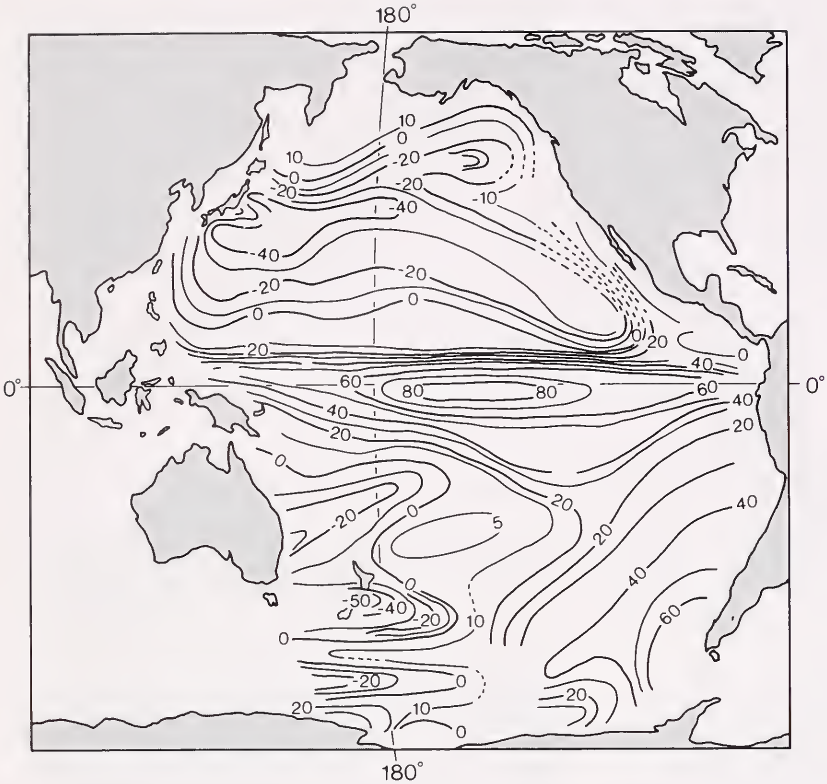


Figure 4. Horizontal distribution of the difference in the partial pressure of CO_2 in seawater and that in the atmosphere, expressed in parts per million, in the Pacific Ocean. Negative values imply a CO_2 flux from the atmosphere to the ocean, and positive values imply a flux from the ocean to the atmosphere.

There is also another difficult calculation. While the result of calculations to date indicates that a significant amount of CO_2 supplied to the atmosphere from fossil fuel combustion since the Industrial Revolution has been absorbed into the oceans (about 30 to 70 percent of the total), we cannot make suitably precise statements about the exact destination of a large portion of the atmospheric CO_2. We must therefore continue to make strenuous efforts to find the missing sink.

Yasushi Kitano is Professor Emeritus at Nagoya University, and Professor of Geochemistry at Sugiyama Jogakuen University, Nagoya. Masayuki Tanaka is Professor of Physical Climatology at Tohoku University, Sendai, Japan.

Selected Readings

Fushimi, K. 1987. Variation of carbon dioxide partial pressure in the western North Pacific surface water during 1982/83 El Niño event. *Tellus* 39B: 1–2 (Special issue on atmospheric carbon dioxide).

Inoue, H., and Y. Sugimura. 1986. Distribution of pCO_2 and $\delta^{13}C$ in the Southern Ocean, south of Australia. *Mem. Natl. Inst. Polar Res., Spec. Issue* 40: 454–461.

Inoue, H., Y. Sugimura, and K. Fushimi. 1987. pCO_2 and $\delta^{13}C$ in the air and surface seawater in the western North Pacific. *Tellus* 39B: 1–2 (Special issue on atmospheric carbon dioxide).

Miyake, Y., Y. Sugimura, and K. Saruhashi. 1975. The carbon dioxide content in the surface waters in the Pacific Ocean. *Records of Oceanographic Works in Japan* 12: 45–52.

Tanaka, M., T. Nakazawa, and S. Aoki. 1983. Concentration of atmospheric carbon dioxide over Japan. *J. Geophy. Res.* 88: 1339–1344.

Tanaka, M., T. Nakazawa, and S. Aoki. 1987. Time and space variations of tropospheric carbon dioxide over Japan. *Tellus* 39B: 1–2 (Special issue on atmospheric carbon dioxide).

Tanaka, M., T. Nakazawa, and S. Aoki. 1987. Seasonal and meridional variations of atmospheric carbon dioxide in the lower troposphere of the northern and southern hemispheres. *Tellus* 39B: 1–2 (Special issue on atmospheric carbon dioxide).

Tanaka, M., T. Nakazawa, M. Shiobara, H. Ohshima, and S. Aoki. 1987. Variations of atmospheric carbon dioxide concentration at Syowa Station (69°00′ S, 39°35′ E), Antarctica. *Tellus* 39B: 1–2 (Special issue on atmospheric carbon dioxide).

Cormorant Fishing on the Nagara River

by Zempei Yamashita

(Cormorant Fisherman of the Imperial Household Agency)

Today cormorant-fishing on the Nagara River in Gifu, a tradition that can be traced back 1,050 years, is the only surviving example of a unique fishing method. Cormorant fishing was first developed along the big rivers of Japan—the Kiso, the Nagara, and the Ibi. Nobunaga Oda, a feudal lord, helped the fishery to develop. He treated the cormorant-fishermen kindly, giving some of them the honorable position of U-Shō (Master-Cormorant Fisherman).

In the days of the Tokugawa Shogunate, cormorant fishing was brought under the direct control of Owari-Han (a feudal clan), one of the three descendants of the shogunate. They issued 10 ryo ($2,500) for the purchase of rice for each of 21 master cormorant fishermen (14 of them were at Nagara, seven at Oze) and ordered them to send in fresh water trout—sushi (pressed boiled rice with fish) packed in four pails to Edo Castle (the Shogunate's palace in Tokyo) once a month from May to August every year.

To protect cormorant fishing, the feudal lord ordered all the villages on the 12 branches of the Nagara River from Gujō County to Ampachi County of Mino Province not to construct fish weirs or build dams for irrigation, or net fish ahead of the cormorant fishing boats.

Norinaga Motoori (a famous Japanese classical scholar of the day), has written:

> No where but in the Nagara can we see
> That antique sight of cormorant fishing,
> So picturesque and impressive,
> Bonfires reflected in the water rushing.

In England, around the 18th century, cormorant fishing was practiced as a sport among the courtiers. Thus cormorant fishing survived under the protection of the privileged class of each era.

As time passed, the general public came to take an interest in this form of fishing and thus cormorant fishing became a tourist attraction.

Zempei Yamashita

Even in the remote days of 1688 under the Tokugawa goverment, Bashō (one of the greatest poets of Japan) wrote:

"The cormorant fishing of the Nagara River in Gifu is very popular all over the country. True to its fame, that exciting event is quite beyond my description. I can't help feeling awfully sorry to part and I heartily wish to let my acquaintances take a look at the sight.

After the brightest sight
Of the cormorant-fishing,
There remains a loneliness alone,
The gaiety diminishing.

The Imperial Restoration of 1868, which renovated the whole Japanese administrative system, brought the 300-year-old protective policy of the Tokugawa Shogunate to an end. Then cormorant fishing faced great unexpected difficulties, but managed to survive and has been maintained through the protection of the Emperor since 1890, under the direct control of the Imperial Household Department.

People throughout Japan, not to mention men of high rank from other countries of the world who visit this country, like to have a chance to appreciate this classical style of fishing. So night after night, year after year, the bonfires of the cormorant fishing are reflected in the waters of the Nagara.

Sea Cormorants Used

*We use a "sea cormorant" in the cormorant-fishing at Nagara. Cormorants are found all over the world except in the Middle-Pacific area; four kinds of cormorants are found in Japan—*Phalacrocorax corbo hanedae *(river cormorant),* Phalacrocorax capillatus *(sea cormorant),* Phalacrocorax pelagicus *(princess cormorant), and* Phalacrocorax urile *(island cormorant).*

A sea cormorant is bigger than a river cormorant and so the former can catch bigger and more fish than the latter.

Sea cormorants can endure long labor and, being mild-tempered, they do not struggle for the game with one another. River cormorants are small and hot-tempered.

Cormorants are captured at the seashore at Ishimama, Ibaragi Prefecture, and transported from there. Immediately after the wild cormorants are captured, cotton thread is stitched into the skin just under both under-eyelids and then thread is tied at the top of the head, covering the eyes with the under-eyelids.

The masters (Master Cormorant Fishermen) let the cormorants bathe in warm water and wipe their bodies with hemp-cloth, thus washing off the filth. Then the masters daub powdered plaster on the whole body of the bird. When the plaster is dried by the heat of the sun and the body of the bird itself, nasty things, such as lime (used in the capture of the birds), fall off with the plaster. This procedure is repeated several times. The wild cormorant, wild-tempered at first, gradually comes to be mild-tempered during this process. After the masters are sure that the cormorants have cooled down, the thread binding the eyelids is cut off and the eyes are let open.

Then from one wing they cut off at the roots eight or nine feathers, leaving two or three of them. The feathers of the other wing are not cut. The purpose of this is to prevent the cormorants from keeping their balance during flight, thus disabling them from flying far off. The beaks of cormorants are very sharp, so the masters trim them with knives so that if they peck at other birds the wound will not be severe.

Cormorants are usually kept in a bamboo cage called "U-Kago" (cormorant cage). Four birds are kept in each cage. The masters try to keep in close contact with cormorants: for example, they take the cormorants out of the cage and massage their heads or stomachs; so that the birds get accustomed to living with the fishermen. The least expression of anger on the part of the master affects the cormorants so that the master tries to treat the cormorants as tenderly as possible. Everyday, early in the morning, they bind the cormorants with hemp strings around their necks and let them bathe in the river.

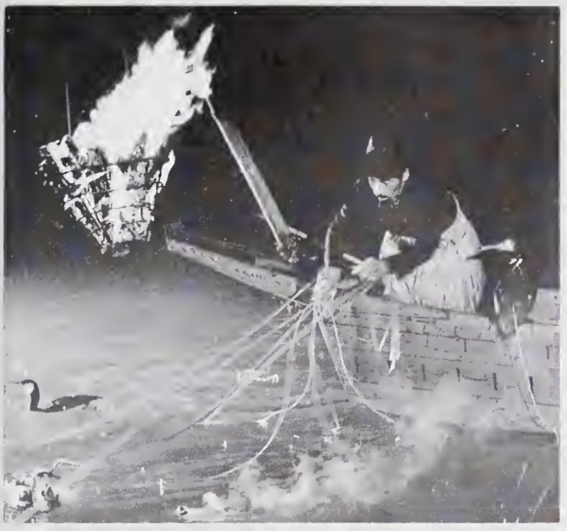
It takes about two weeks for wild cormorants to get accustomed to fresh water and to living on land with the masters and other people. During this period, the cormorants are fed with fresh-water fish.

The cormorants do not fish in the river until they have adapted themselves to the circumstances. So the master gives them food with his own hands. Each cormorant takes about 750 grams of fish a day, though the amount varies a little with the size of the bird. The average weight of a cormorant is around 2.8 kilograms.

The period from October 16 to May 10 of the next year is called the Feeding Season. In this season, the Master Cormorant Fishermen put forth all their efforts to guard the health of the cormorants and to provide food for them. Today, with the rapid decrease in abundance of river fish, circumstances are sometimes so unfavorable for the cormorant fishermen that they must purchase fish, instead of taking the cormorants to the river for feeding.

When the masters are sure that the cormorants have eaten fish to some extent, they drive them to some suitable place and check each one, making the ones that have eaten too much throw up some of the fish they have eaten and giving them to the ones that have eaten little, thus adjusting their day's ration.

The opening of the cormorant fishing season is May 11. There are two forms of



ishing training session. (Photos courtesy of John Kanwisher)

cormorant fishing. In one form, the cormorant fishermen set the cormorants free in the water and let them catch fish while they watch from either land or boat. In the other form, the fishermen manage the cormorants at the end of ropes they hold in their hands. Which is chosen depends on the condition of the river. For example, in calm water, such as a pond or a marsh, cormorants can be set free; but on a rapid river, the fishermen need to have lines to hold the cormorants.

At present, cormorant fishing takes place on the Nagara River every night from May 11 to October 15, except on a full moon night or when the water has risen or is muddy. The fish caught are mainly ayu or fresh water trout. The time and place varies every night.

There are six fishing boats at Nagara (Gifu City) and three at Oze (Seki City). When they go cormorant fishing, four men are always on board. The Master-Cormorant-Fisherman stands at the bonfire near the bow wearing a long-traditioned costume of Kazaori-Eboshi (a kind of hat) and Koshi-mino (a kind of loin-cloth made of straw). He holds tight in his left hand the lines of a dozen cormorants, adjusting them with his right hand so that the lines do not get entangled, puts pine wood on the bonfire, and lets the cormorants throw up fish from their gullets. Just behind the master, the Naka-Nori (center boatman), manages the boat with an oar. A little behind the center of the boat, Naka-U-Zukai (center cormorant fisherman or an assistant fisherman) handles four to six cormorants, and at the stern of the boat, Tomo-Nori (stern boatman) helps the center boatman manage the boat. With the exception of the master, all hands wear livery coats.

The men, the cormorants, and the boat are in perfect harmony. Rain or shine, the cormorant fishermen's gallant shout "Ho-ho!" can be heard on the rushing water of the Nagara. Some 70 houseboats, carrying anywhere from 8 to 30 people, are available for tourists wanting to witness the spectacle.

The master tries to let the cormorants catch as many fish as they can, but he has to be very careful that the lines do not get tangled. There are many obstacles lurking in the bottom of the river. If the cormorant has become entangled in such an obstacle, the fisherman must instantly cut off the hand line so the cormorant may escape from drowning by coming up to the surface.

When the fishing is over, the cormorants are drawn up in two lines in order of age (the eldest first) along the side of the bow of the boat near the bonfire. After their wings have dried, they are placed in their cage and returned home. The fresh water trout that have been caught are sorted immediately after returning home, and are packed in ice till the next morning when they are carried to the market and sold.

The Emperor of Japan

Portrait by Dorothy Meinert

Marine Biologist

by Paul R. Ryan

"We have been impressed by the enterprise and expertise of those in Japan who are broadening our knowledge of the oceans and showing the way toward man's wise use of them."

So said then Director Paul M. Fye on welcoming the Emperor of Japan to the Woods Hole

Oceanographic Institution on October 4, 1975. "We recognize especially the value of your continuing support of marine science in achieving this high degree of excellence," he added.

This issue of *Oceanus* examines "the enterprise and expertise of those in Japan who are broadening our knowledge of the oceans." This profile recognizes the Emperor's "continuing support of marine science" in Japan.

Emperor Hirohito was born in Tokyo on April 29, 1901, the eldest son of Emperor Taisho. He attended Gakushuin (then Peers School) and was tutored by the Special Institute established for the Crown Prince's education.

Grand Chamberlain Yoshihiro Tokugawa, who has served the Emperor for 50 years and who granted this writer an interview in the Imperial Palace in Tokyo, said the Crown Prince's interest in biology began in the 6th grade (1913) when he saw his first collection of marine specimens. Tokugawa is closer to the Emperor than any other member of the official household staff. He also is thoroughly familiar with all aspects of the Emperor's interest in marine biology. Prior to the end of World War II, when militarists in the palace were strongly opposed to Japan's surrender, it was Tokugawa who smuggled the Emperor's surrender speech out of the palace for broadcast on Japanese radio on 15 August 1945.

From March through September 1921, Crown Prince Hirohito toured Europe, visiting Britain, France, Belgium, the Netherlands, and Italy. Following his return to Japan, the Crown Prince married Princess Nagako, eldest daughter of the late Prince Kuni, in January 1924.

After the death of Emperor Taisho in December 1926, Crown Prince Hirohito was enthroned as the 124th Emperor, his Ceremony of Accession to the Throne taking place in November 1928.

As the years passed, the Emperor's interest in marine biology continued to grow. He often collected specimens of the flora and fauna in and around Sagami Bay, site of an imperial vacation villa. He soon built his own marine laboratory near a mulberry garden on the grounds of the Imperial Palace in Tokyo, employing two marine biologists and a specialist in flora to aid in the classification work. Today, at the age of 85, he still spends Monday, Thursday, and Saturday afternoons in the laboratory. Over the years, more than 28,000 specimens of marine life have been sent to him from all over the world for classification purposes.

The Emperor and Empress have five living children and several grandchildren. Two daughters, Shigeko (born in 1926) and Sachiko (born in 1927), are deceased. Crown Prince Akihito, their eldest son, was born in 1933 and was proclaimed heir apparent. In recent years, he has taken over many of the ceremonial duties of his aging father. He is married to Michiko Shoda, and has two sons and a daughter.

The Crown Prince is also a marine biologist, specializing in the study of gobies. He has published 24 papers in the *Japanese Journal of Ichthyology* and is the author of several entries on gobies in *Fishes of the Japanese Archipelago*. In 1985, he was named Honorary

The Emperor on a collecting trip at Hayawa, August 8, 1949. (Photo courtesy of Imperial Household)

President of the Second International Conference on Indo-Pacific Fishes.

Prince Hitachi, born in 1935, is the younger son. He is engaged in cancer research in Tokyo's National Cancer Center. The three living daughters are Kazuko, born in 1929, Atsuko, born in 1931, and Takako, born in 1939. The imperial family devote much of their time to preserving the grace and beauty of traditional Japanese culture. Among the classical traditions that the family has sustained is *gagaku*. Public performances of *gagaku*, designated an "important intangible cultural treasure," are held within the palace grounds every spring and fall. The genre includes Japan's most ancient dance and music, dating from the fifth century. *Waka* poetry, a distinctly Japanese form of literature, is another ancient art (eighth century) nourished by the Imperial family.

Among the ancient customs unique to Japan is *ugai*, or fishing with trained cormorants. There is an Imperial Fishery on the Nagara River in Gifu Prefecture where night fishing with cormorants has become a major tourist attraction (see story page 83).

The Emperor's first visit outside Japan (as Emperor) occurred in 1971, when he visited Belgium, Britain, West Germany, and four other European nations on an 18-day tour. Four years later, in September and October 1975, he visited the United States for 15 days. He was accompanied by the Empress on both trips.

The Emperor arrived in Woods Hole, Massachusetts, on 4 October 1975. He was particularly interested in exchanging ideas with local scientists on marine hydrozoans, a group of primitive animals without backbones that are very common on seaweed, shells, and pebbles in shallow waters over much of the world. At least 40 species are common in the Woods Hole area.

Commonly several inches high, hydroids represent animals ancient in the Earth's history. An early American naturalist wrote:

The Emperor's Biological Laboratory on the Palace grounds. (Photo courtesy of Imperial Household)

"To the lover of what is beautiful, (these hydroids) exhibit a variety of forms unsurpassed in delicacy, grace, and harmony of color, by even the fairest flowers. . ." However, it should be noted that while these distant relatives of the menacing Portuguese man-of-war may appear flower-like in the stage of life when they are attached, their cells and tissues are performing the "animal" functions of digestion, nervous and muscular activity, and reproduction.

The Emperor's interest in hydrozoans focuses on the phase of life history after the attached hydroids have released tiny, free-swimming, jellyfish-like offspring (each called a medusa). Male and female medusae produce eggs and sperm which unite and develop, like any fertilized egg, into a new hydroid that attaches to rock, wharf, or plant and begins another life cycle. Each individual resembles its grandparent (medusa or hydroid), but never its parent, yet every cell contains the same hereditary material whether contained in the flower-like hydroid or the tiny, free-swimming medusa.

"The Last One to Go"

When the Emperor visited the Marine Biological Laboratory during his tour of Woods Hole marine institutions, he paused to view the haunting statement by "The last one to go," a document that has captured the interest of hundreds of visiting Japanese scientists during the last 40 years.

Shortly after American forces entered Japan at the close of World War II, units of U.S. Submarine Squadron 20 occupied a midget submarine base. The base had been a marine biological station operated by the University of Tokyo. The occupying forces found the following notice posted on the door:

> This is a marine biological station with her history of over sixty years.
>
> If you are from the Eastern Coast, some of you might know Woods Hole or Mt. Desert or Tortugas.
>
> If you are from the West Coast, you may know Pacific Grove or Puget Sound Biological station.
>
> This place is a place like one of those, Take care of this place and protect the possibility for the continuation of our peaceful research.
>
> You can destroy
> the weapons and
> the war instruments
> But save the civil equipment
> for Japanese students.
>
> When you are through
> with your job here
> Notify the University and
> let us come back to our
> scientific home.
>
> **(Signed)**
> **The last one to go.**

The last one to go was marine biologist Katsuma Dan. Dan had been educated at the

University of Pennsylvania (Ph.D., 1934), where he met his wife and scientific colleague, Jean Clark Dan. He had worked at the Marine Biological Laboratory from 1931 to 1934 and again in 1936.

After the war, he was Professor of Zoology at Tokyo Metropolitan University, which he also served as President from 1964 until 1972. One of Professor Dan's great discoveries was the isolation of the mitotic spindle, which has contributed greatly to the understanding of how cells divide. Considered a landmark in world biology, the discovery was made at the MBL during the 1950s jointly with Professor Daniel Mazia. Later Professor Dan returned to teach in MBL's Embryology Course in the company of James Ebert, former president of MBL.

During his visit to WHOI, the Emperor met with several institution scientists for scientific consultation and observation. These included Howard L. Saunders, Susumu Honjo, David A. Ross, and John H. Ryther, among others.

The Emperor and the Aurora

The Emperor is kept informed on the latest scientific developments by frequent palace lectures that he arranges and attends. It is considered to be quite an honor to be summoned to the palace for a lecture, which may be on any scientific topic of interest to the Emperor.

S.I. Akasofu of the Geophysical Institute at the University of Alaska in Fairbanks was summoned to the palace on 3 October 1985 to lecture on the aurora.* He wrote of his experience in EOS, a publication of the American Geophysical Union:

> *After my slide presentation, he [the Emperor] asked how we confirm ancient sighting reports of the aurora in Japan. He was not satisfied with my response that anomalous events in the sky were well documented in an ancient publication entitled* Japanese Meteorological Data *and asked further how one could confirm such sightings as auroral events. He was visibly pleased to learn that the dates of these sightings coincided with those recorded elsewhere in the world.*
>
> *Many people still believe that the aurora occurs more frequently as we approach the north magnetic pole. The Emperor was not an exception. Thus, when I told him that this is not the case, he was very puzzled. However, he was delighted when I showed him an image of the ring-shaped aurora taken from the Dynamics Explorer satellite . . . and explained that at the geomagnetic pole, which is located near the center of the auroral oval, the aurora is located well beyond the southern horizon most of the time. He also wanted to know about the auroral spectral composition. "I want to make sure that the auroral green line comes from atomic oxygen, not from molecular nitrogen," he told me.*
>
> *The Emperor was also fascinated by the videotape of a spectacular auroral display that was recorded at our Poker Flat Rocket Range. He asked how often we can observe such a display in Fairbanks (how many days per week, and then how many hours on an active night, and so on).*
>
> *He is interested in astrophysical implications and practical applications of auroral studies and asked a few basic and technical questions about them.*
>
> *The Emperor's chamberlains told me that he stayed awake on the airplane on his trip to Europe and the United States so that he could observe the aurora; on both occasions he did observe some auroral displays. It was an unforgettable hour.*

The Emperor's Powers

As stated in the Constitution of Japan, the Emperor is "the symbol of the State and of the unity of the people," and derives his position from "the will of the people with whom resides sovereign power." The Imperial Throne is dynastic and succeeded to by males of the

* A radiant emission from the upper atmosphere that occurs sporadically over the middle and high latitudes of both hemispheres in the form of luminous bands, streamers, or the like, caused by the bombardment of the atmosphere with charged solar particles that are being guided along the Earth's magnetic lines of force.

Imperial Family in accordance with the Imperial House Law.

The Emperor has no powers related to government and performs only the following acts in matters of state as stipulated in the Constitution:

- Appointment of the Prime Minister as designated by the Diet;
- Appointment of the Chief Justice of the Supreme Court as designated by the Cabinet;
- Promulgation of Constitutional amendments, laws, cabinet orders, and treaties;
- Convocation of the Diet;
- Dissolution of the House of Representatives;
- Proclamation of general elections;
- Attestation of the appointment and dismissal of Ministers of State and other officials and of the full powers and credentials of Ambassadors and Ministers;
- Attestation of general and special amnesty, commutation of punishment, reprieve, and restoration of rights;
- Awarding of honors;
- Attestation of instruments of ratification and other diplomatic documents;
- Receiving of foreign Ambassadors and Ministers; and
- Performance of ceremonial functions.

In performing these duties, the Emperor acts only with the advice and approval of the Cabinet, and the Cabinet is responsible for them.

The Imperial Palace

Located in the center of Tokyo, the Imperial Palace grounds extend over approximately 284 acres surrounded by a stately moat. Home of the Tokugawa shogun for nearly 280 years, the site passed to the Imperial Household with the Meiji Restoration of 1868.

The Imperial Palace was built in 1968. Though constructed of modern materials, it is designed along very simple, traditional lines. The Emperor and Empress's private quarters, the Fukiage Residence, is a two-story structure set in the midst of a densely wooded area.

Specimen cabinets in Emperor's laboratory. (Photo courtesy of Imperial Household)

The Crown Prince and Princess and other members of the Imperial Family have their own residences outside the palace grounds.

A Level of Attention

As Japan continues to rely on the oceans for many of its resources, the Emperor continues to be a symbol for wise, environmentally sound use of the waters off his shores. As articles in this issue attest, the marine sciences occupy an important level of attention within the Japanese government.

Paul R. Ryan is Editor of Oceanus, published by the Woods Hole Oceanographic Institution.

Scientific works written by the Emperor:

A Review of the Hydrozoa of the Family Clathrozonidae with Description of a New Genus and Species from Japan
Some Hydroids of the Amakusa Islands
Additional Notes on Clathrozoon wilsoni *Spencer*
Some Hydrozoans of the Bonin Islands
Five Hydroid Species from the Gulf of Aqaba, Red Sea
Hydroids from Oshima and Niijima
A New Hybrid Hydractinia bayeri *n.sp. (Family Hydractiniidae) from the Bay of Panama*

Collaborative works:

Flora Nasuensis
Supplement to Flora Nasuensis
Myxomycetes of the Nasu District
Flora Suzakiensis
Nova Flora Nasuensis

Works based on data collected by the Emperor:

Opisthobranchia of Sagami Bay
Supplement to the Opisthobranchia of Sagami Bay
Ascidians of Sagami Bay
Myxomycetes of Nasu District
Crabs of Sagami Bay
Hydrocorals and Scleractinian Corals of Sagami Bay
The Sea Shells of Sagami Bay
The Sea-stars of Sagami Bay
The Crustacean Anomura of Sagami Bay
On the Genus Ephelota (Ciliophora suctoria) *from the Coasts of Izu Peninsula and Niijima*
The Brittle Stars of Sagami Bay

letters

> *Let us love winter, for it is the spring of geniuses.*
> **—Pietro Artino**
> *In all countries when nature does the most, man does the least.*
> **—Charles Caleb Colton**
> *(from FORBES, 12 January 1987, p. 308)*

To the Editor:

As usual I came to work early (5:40 a.m.). Since I am the only early bird around here I am enjoying this quietude before other bureaucrats trickle in two hours from now. Here and now I enjoy my contemplation.

Death is quite much a part of living. Charles Palmer died on 30 December 1986. Charles was married to Bobbie who works as the secretary of this office. His memorial service was held on 3 January 1987. Charles was a handsome man in his mid-40s. Bobbie now has a son and a daughter in teens to take care of. However painful, healing process will soon take place in Bobbie's family.

Since Bobbie has not returned back to work I have been cleaning up her desk daily. Mails are opened, sorted, and distributed. Some official letters I type. At least I can do this much for her and for the office.

Someday I, too, shall die. I hope it be peaceful and happy. And I think it can be. Especially when I live well one day at a time, carrying on whatever task I set out to do for humanity. Thus no regret when time comes.

As an oceanographer I have contributed. With Buck Ketchum, Dana Kester, and Iver Duedall, we collectively have contributed for the abatement of marine pollution. Our scholarly six-volume series entitled *Wastes in the Ocean* that were issued by John Wiley Publisher in New York, 1983–85, are monumental. Knowledge synthesized helps humanity broadly.

I wish to continue to distill my life. I wish to leave behind some concise products which our progenies can use. I do not wish to leave behind me any garbage. Since I am forever told that "garbage in, garbage out," I do not wish to intake any unnecessary garbage when avoidable. When unavoidable I will follow the advice of Pietro Artino who is alleged to have said "let us love winter, for it is the spring of geniuses." (I prefer to have the warmth of sunshine.) I have had enough wintry days in my life (two wars and five years of starvation); I do not need to have them much more. Here and now I must start anew to produce.

I think it would be nice to have a death of poet. That is that on my last day on earth I shall write the most beautiful poem thanking for the life I have had. I think that it can be done, for some Japanese poets have done so already (some wrote poems at their deathbeds). Life, to me, is a precious gift, not an entitlement, I am privileged to experience.

It has been a beautiful life I have had. Whatever I can still experience I shall enjoy its goodness. I'll also continue to avoid the man-made ugliness as much as possible. I hope that you, too, enjoy the beauty of your life continuously.

Momiji
Fallswood, Maryland
Early Wednesday morning
7 January 1987

EDITOR'S NOTE: Attached to the letter at left was this poem.

New Year's Poem

Symphony of my life
Continues on on earth;
It flows gently, warmly
To celebrate this life
With waltzing squirrels
Over the new snowfield.

Softly I tread across,
Listening to the sound
Of falling new snow.
I hear it; I don't hear it.
I see the snow;
I am the new snow.

Symphony of my life
Continues on on earth;
It shares its beauty
With fellow humans
As the snow's warmth
Nurtures our spring buds.

—Momiji

1 January 1987

EDITOR'S NOTE: I am constantly surprised by the activities of oceanographers who probe the inner oceans. Momiji, the poet, is Dr. Paul Kilho Park, Director of the Japan and China Programs in the International Activities Office of the National Oceanic and Atmospheric Administration, Rockville, Maryland.

To the Editor:

In reference to the article by Ms. Scavotto in *Oceanus*, Volume 29, No. 3, Fall, 1986, my congratulations for acknowledging the (albeit limited) role of aquariums in the business of science. Her list of the 36 aquariums of the United States, however, falls somewhat short of the truth. The number is closer to 45 and if the many federal and state hatcheries with public exhibits are included, the number climbs to about 100.

Worst of all, you forgot us; the aquarium at the University of Georgia's Marine Extension Center in Savannah, Georgia. We are similar in size to your neighbor down the street [in Woods Hole] and like them, committed to the exhibit of local marine and estuarine vertebrates and invertebrates. Annually, the aquarium serves about 60 thousand visitors in addition to about 15 thousand students who come to the Center during the year for short courses in the marine sciences.

David Miller, Curator
Marine Extension Service
Skidaway Island,
Savannah, Georgia

To the Editor:

I am writing, albeit a bit late, to compliment you on your recent article about research at public aquariums in the United States, which was published in the Fall 1986 issue of *Oceanus*. Your select overview was well done, and I was pleased to see the section on the Smithsonian's Marine Systems Laboratory, which most authors omit or else fail to recognize its significance.

I do have a minor criticism, however. Although you did state that a complete review of those aquariums with research programs was not possible because of space limitations, I would have hoped your listing of aquariums (p. 34) would have been more up to date and complete. I suspect part of the problem is in the sources you chose to use; both A.A.Z.P.A. and the Official Museum Directory usually only list MEMBER institutions, and many aquariums with major research components are not members of these organizations for a variety of reasons.

For your records, I would like to comment on those institutions which you did list, as well as include a partial list of those institutions which were not listed.

Listed:

1) *The Cleveland Aquarium* closed its doors to the public in the spring of 1986, due to funding problems within the city, and has been temporarily moved into the Cleveland Metroparks Zoo. A new waterfront aquarium for the city is being planned. Their research areas are varied, but they are perhaps best known for inventing and perfecting synthetic sea salts, eventually resulting in the formation of Aquarium Systems, Inc. (Mentor, Ohio), manufacturers of Instant Ocean.

2) *The Depoe Bay Aquarium* is essentially a small tourist stop on the Oregon coast and, save for participating in the regional marine mammal stranding network, has no formal research programs.

3) *Oceana Marine Life Center* located within Cedar Point Amusement Park is essentially a very small-scale Sea World (that is, animal shows) and has no current research program.

Partial listing of those public aquariums with major research components not mentioned in the article:

1) Oregon State University Hatfield Marine Science Center Public Aquarium
2030 S. Marine Science Drive
Newport OR 97365
(503) 867-3011
Dr. Lavern J. Weber—Director
Mr. Kenneth Yates—Aquarist

2) Oregon Coast Aquarium
1 Ferry Slip Road
P. O. Box 78
South Beach, OR 97366
(503) 867-3474
Mr. Bruce Henderson—Executive Director

3) National Aquarium
Dept. of Commerce Building
14th and Constitution Avenue
Washington, D.C. 20230
(202) 377-2827
Mr. Brian Montague—Curator

4) Gulf Coast Research Laboratory
J. L. Scott Marine Education Center
1650 East Beach Street
Biloxi, MS 39530
Mr. Gerald Corcoran—Director

5) North Carolina Aquariums:
a) Roanoke Island
Manteo, NC 27954
(919) 473-3493
b) Bogue Banks
Atlantic Beach, NC 28512
(919) 247-4003
c) Fort Fisher
Kure Beach, NC 28449
(919) 458-8257

6) Virginia Marine Science Museum
717 General Booth Blvd.
Virginia Beach, VA 23451
(804) 425-3474

7) Cabrillo Marine Museum
3720 Steven White Drive
San Pedro, CA 90731
(213) 548-7562
Dr. Susanne Lawrenz-Miller—Director

8) Kipp Aquarium
Houston Zoological Gardens
1513 Outer Belt Drive
Houston, TX 77030
Nelson Herwig—Curator

9) Bowling Green State University Marine Laboratory
B.G.S.U.—Dept. of Biological Sciences
Bowling Green, OH 43403
(419) 372-0330
Prof. Cynthia S. Groat—Coordinator

10) Miscellaneous zoos with large aquariums:
a) Toledo Zoo
b) Pittsburg Aqua Zoo
c) St. Louis Zoo
and of course my aquarium:

11) Virginia Institute of Marine Science (VIMS) Aquarium
School of Marine Science
The College of William and Mary
Gloucester Point, VA 23062

I hope I have helped update your information. Thanks again for the timely and well-written article.

Joseph M. Choromanski, Aquarium Curator,
Dept. of Marine Advisory Service,
Virginia Institute of Marine Science
College of William and Mary,
Gloucester Point, Virginia

book reviews

***Lighthouse*, by Tony Parker. 1986.**
Published by Hippocrene Books, New York, N.Y. 288 pp.
$9.95

"It's a different world you see out there, a totally different world; you couldn't imagine it for yourself and I couldn't explain." So author Tony Parker is told before gaining admittance into the mysterious, fraternalistic society of Britain's lighthouse service.

It seems that all 93 of Britain and Wales' lighthouses are presided over and jealously guarded by the Elder Brethren of the Trinity Corporation. Only after much persistent hounding by the author do the brethren make an exception to their time-honored traditions of secrecy, and grant an outsider the rare opportunity of visiting various lighthouses and observing firsthand the monk-like daily and nightly routine of lighthouse life.

From hundreds of taped interviews with keepers, keepers' wives, and others connected in various ways with the service, Parker creates a few composite characters and attaches them to three different stations, accordingly dividing the book into three sections. The first section centers on a land light (built on the mainland), the second on a rock light (built on an island), the third on a tower light (rising straight out of the sea).

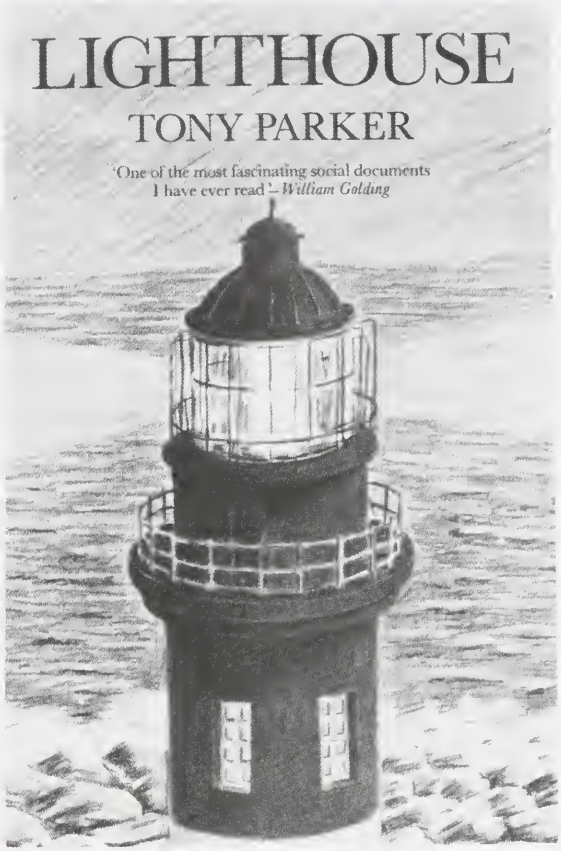
Each section is a collection of skillfully juxtaposed interviews which again are composites of actual tape-recorded conversations. By always remaining in the background, sometimes disappearing, the author gives the interviews a sense of real immediacy. I found myself totally involved in the minute physical descriptions of the routine of lighthouse duty—the lighting of the light at sunset, checking that it is functioning properly during the night, servicing its machinery and cleaning the lenses, and recording the details of the weather.

Even more compelling, though, are the portraits in human nature that the more intimate, soul-searching portions of the conversations reveal. Keepers tell of their past, their reasons for entering the service, their subsequent feelings about their decision—about living away from their wives and children for months at a time in cramped quarters with two other men, working monotonous, endlessly rotating shifts, surrounded by the lonely enormity of the sea. Likewise, we listen as the wives tell their stories—alone much of the time, their men in an isolated all-male world, to which they don't belong and can never really share.

We meet Alf, an alcoholic for whom the lighthouse provides a fixed point of meaning in an otherwise meaningless world; Bobbie, an ex-prisoner who derives a sense of freedom and strength from the surrounding sea; Alex, for whom the tower is an escape, an ivory tower far removed from the real-life issues that his wife and children must face daily, and others, each with a different story to tell.

The long periods of introspection, the loss of the sense of time, the disorientation are healthy to some, destructive to others, but mind-altering to all. Keeper George Preston talks about the midnight shift:

> *I suppose every man feels the same; sometimes it can get, well, not exactly oppressive, but the sort of time you find your thoughts beginning to ramble. If there's anything on your mind you'll find yourself thinking about it. Sometimes you just sit and stare, other times you'll get weird ideas and funny feelings come into your head. Perhaps like that somehow you're the only person left in the world, everyone else has disappeared; there aren't any other people anywhere, no one else alive but you.*



With each section taking us to a station more remote, with the men more isolated and yet closer together in more cramped living quarters, Parker sets the stage for a neat study in human nature. How and why the characters live in their self-contained little worlds sheds much light (if you'll pardon the pun) on big questions in the "real" world such as why people choose to be together, why they need each other, and why they need to be separate. A rare insightful book.

Michelle K. Slowey,
Editorial Assistant,
Oceanus

Oceanus back issues

Changing Climate and the Oceans

Vol. 29:4, Winter 1986/87—Forecasts of near-term climate change have challenged scientists to understand complex interactions between the atmosphere, the ocean, and the Earth. The wobbling Earth, changing sunlight, carbon dioxide, polar ice sheets, and deforestation—along with a new generation of research satellites—are described.

The Titanic Revisited

Vol. 29:3, Fall 1986—The second visit to the site, and the first visit by *Alvin* and the remote vehicle, *Jason Jr.*, is described, and new findings are reported. Other articles address the radioactivity of the Irish Sea, the growth of U.S. aquaria, Japanese ocean architecture, and the collaboration of John Steinbeck and Ed Ricketts.

The Great Barrier Reef: Science & Management

Vol. 29: 2, Summer 1986—The Great Barrier Reef off Australia's Pacific coast is the world's largest coral reef system. This comprehensive special issue describes the structure, evolution, life, and management of this colorful and complex system. Widely useful to all with interests in special ecosystems.

The Arctic Ocean

Vol. 29:1, Spring 1986—It's frozen. It's remote. But—scientists, the military, lawyers, corporations, governments, and investors are paying particular attention to the Arctic. Some call it a stampede. Find out who, why, and what it means. Topics include exploration, U.S. and Soviet security, sea ice, climate, shipping, pollution, and policy.

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other available issues…

- **The Titanic: Lost and Found,**
  Vol. 28:4, Winter 1985/86—The *Titanic's* 1912 loss, and 1985 discovery.
- **The Oceans and National Security,**
  Vol. 28:2, Summer 1985—The oceans from the viewpoint of the modern navy, strategy, technology, weapons systems, and science.
- **Marine Archaeology,**
  Vol. 28:1, Spring 1985—History and science beneath the waves.
- **The Exclusive Economic Zone,**
  Vol. 27:4, Winter 1984/85—Options for the U.S. EEZ.
- **Deep-Sea Hot Springs and Cold Seeps,**
  Vol. 27:3, Fall 1984—A full report on vent science.
- **El Niño,**
  Vol. 27:2, Summer 1984—An atmospheric phenomenon analyzed.
- **Industry and the Oceans,**
  Vol. 27:1, Spring 1984
- **Oceanography in China,**
  Vol. 26:4, Winter 1983/84
- **Offshore Oil and Gas,**
  Vol. 26:3, Fall 1983
- **Summer Issue,**
  1982, Vol. 25:2—Coastal resource management, acoustic tomography, aquaculture, radioactive waste.
- **Summer Issue,**
  1981, Vol. 24:2—Aquatic plants, seabirds, oil and gas.
- **The Oceans as Waste Space,**
  Vol. 24:1, Spring 1981.
- **Senses of the Sea,**
  Vol. 23:3, Fall 1980.
- **Summer Issue,**
  1980, Vol 23:2—Plankton, El Niño and African fisheries, hot springs, Georges Bank, and more.
- **A Decade of Big Ocean Science,**
  Vol. 23:1, Spring 1980.
- **Ocean Energy,**
  Vol. 22:4, Winter 1979/80.
- **Ocean/Continent Boundaries,**
  Vol. 22:3, Fall 1979.
- **Sound in the Sea,**
  Vol. 20:2, Spring 1977—The use of acoustics in navigation and oceanography.

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- **Offshore Oil and Gas,**
Vol. 26:3, Fall 1983

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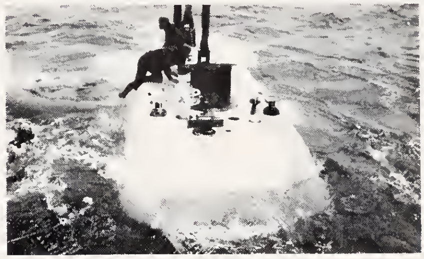

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